Research and Recovery of Snake River Sockeye Salmon

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RESEARCH AND RECOVERY OF SNAKE RIVER SOCKEYE SALMON

ANNUAL REPORT 1994

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ABSTRACT

On November 20, 1991, the National Marine Fisheries Service listed Snake River sockeye salmon Oncorhynchus nerka as endangered under the Endangered Species Act of 1973. In 1991, the Shoshone-Bannock Tribe and the Idaho Department of Fish and Game initiated the Snake River Sockeye Salmon Sawtooth Valley Project to conserve and rebuild populations in Idaho.

In 1994, we estimated the total September Redfish Lake O. nerka population at 51,529 fish (95% CI, ± 33,179). Total O. nerka density and biomass was estimated at 125 fish/hectare (± 81) and 2.1 kg/hectare, respectively. The Alturas Lake O. nerka population was estimated at 5,785 fish (± 6,919). The total density and biomass of Alturas Lake was estimated at 27 fish/hectare (± 33) and 0.7 kg/hectare, respectively. The total O. nerka population estimate for Pettit Lake was 14,743 fish (± 3,683). We estimated total density and biomass for Pettit Lake at 128 fish/hectare (± 32) and 4.4 kg/hectare, respectively. Stanley Lake O. nerka total population size, density, and biomass was estimated at 2,695 fish (± 963), 37 fish/hectare (± 13), and 0.5 kg/hectare, respectively.

Estimated numbers of O. nerka outmigrant smolts passing Redfish Lake Creek and Salmon River trapping sites increased in 1994. We estimated 1,820 (90% CI, 1,229 - 2,671) and 945 (90% CI 331 - 13,000) smolts left Redfish and Alturas lakes, respectively.. The total PIT tag detection rate at mainstem dams for Redfish Lake outmigrants was 21% in 1994. No Alturas Lake outmigrants were detected at any of the downstream facilities with detection capabilities (zero of 50 fish).

We released 37 ultrasonic-tagged, maturing O. nerka adults into Redfish Lake in 1994. Tagged fish were tracked to identify spawning-related activity and to detect differences in survival between two principal release groups: (1) fish spawned from returning anadromous sockeye salmon in 1991 and reared to spawning age at Eagle Fish Hatchery (brood year 1991), and (2) O. nerka collected as outmigrants from Redfish Lake in 1991 and reared to spawning age at Eagle Fish Hatchery (outmigrant 1991). We made no observations of sustained site association or spawning-related activity for any of the 37 fish. Additionally, no stationary tags were located or recovered near areas of known or suspected beach spawning activity. Outmigrant 1991 broodstock adults exhibited significantly fewer incidences of stationary and absent tag status (potential mortality indices) and greater incidence of active tag status.

We captured primarily mountain whitefish Prosopium williamsoni (65.8%) in 96 h of trap netting in Redfish Lake. Bull trout Salvelinus confluentus and northern squawfish Ptychocheilus orectonensis comprised 2.4% and 4.2% of the catch, respectively. Bedside shiners Richardsonius balteatus, suckers Catostomus sp., brook trout Salvelinus fontinalis, and O. nerka comprised the remainder of the catch. Because we exceeded our incidental take of O. nerka (under permit by the National Marine Fisheries Service), we were required to discontinue this activity.

We used otolith microchemistry to describe the life history of Redfish Lake O. nerka (progeny of 1991 and 1993 returning anadromous sockeye salmon with known lineage to anadromous female parents). Mean strontium/calcium ratios (Sr/Ca) in otolith nuclei of brood year 1991 progeny showed patterns consistent with ova development in saltwater (Sr/Ca ratio >0.0014). Mean Sr/Ca ratios in otolith nuclei of brood year 1993 progeny produced results less consistent with our expectations. Thirty-six percent (4 of 11 samples) of the Sr/Ca ratios fell between 0.0008 and 0.0014 suggesting that ova development in anadromous sockeye salmon may not be complete when fish enter freshwater. Other factors associated with this migration, such as stress and metabolic rate change, may also confound microchemistry results.

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INTRODUCTION

Numbers of Snake River sockeye salmon Oncorhynchus nerka have declined dramatically over the years. In Idaho, only the lakes of the upper Salmon River (Stanley Basin) remain as potential sources of production. Historically, five Stanley Basin lakes (Redfish, Alturas, Pettit, Stanley, and Yellow Belly lakes) supported sockeye salmon (Bjornn et al. 1968). Currently, only Redfish Lake receives a remnant anadromous run.

In the late 1800's, Evermann (1895) made observations on the distribution and abundance of sockeye salmon in Stanley Basin lakes. During his survey of 1894, he reported observing sockeye salmon in Redfish, Alturas, Pettit, and Stanley lakes. Sunbeam Dam, constructed in 1910 by the Golden Sunbeam Mining Company, was operating at full pool by 1911. Built on the Salmon River approximately 35 km downstream from the mouth of Redfish Lake Creek, the dam remained intact until it was intentionally breached in 1934. During these years, upstream salmon passage was doubtful (Chapman et al. 1990). Following breaching, the first account of sea-run sockeye salmon returning to the Stanley Basin occurred in 1942 when 200 adults were counted in Redfish Lake (Parkhurst 1950). Between 1954 and 1966 a two-way weir (Bjornn et al., 1968) was operated on Redfish Lake Creek. During these years, adult sockeye salmon escapement ranged from 11 fish in 1961 to 4,361 fish in 1955. Estimated smolt outmigration for this same period ranged from 2,133 fish in 1960 to 65,000 fish in 1957. Beginning in 1955, numbers of sockeye salmon reaching Stanley Basin lakes began to decline. By 1962, sockeye salmon were no longer returning to Stanley and Pettit lakes (Chapman et al. 1990). During the 1980's, the greatest adult escapement occurred in 1982 when 50 fish were observed over spawning gravel in Redfish Lake (Hall-Griswold, 1990). Between 1990 and 1993, a total of 13 adult sockeye salmon returned to Redfish Lake. In 1994, only one adult female returned.

The Idaho Department of Fish and Game (IDFG) Sawtooth Fish Hatchery (FH), constructed to mitigate for lower Snake River hydroelectric dams, began recording adult sockeye salmon returns in 1985. Between 1985 and 1989, five adult sockeye salmon were intercepted at the Sawtooth FH weir which lies approximately 2 kilometers upstream of the mouth of Redfish Lake Creek on the Salmon River. The last recording of an adult return at this facility occurred in 1989 when one fish was intercepted; presumably in route to Alturas Lake.

On April 2, 1990, the National Marine Fisheries Service (NMFS) received a petition from the Shoshone-Bannock Tribe (SBT) to list Snake River sockeye salmon as endangered under the Endangered Species Act (ESA) of 1973. On November 20, 1991, NMFS declared Snake River sockeye salmon endangered. Section 4(f) of the ESA requires the development and implementation of a recovery plan for listed species. At the time of this writing, a seven member team (appointed by NMFS) is in the process of preparing the final draft of this document.

The IDFG, as part of their five-year management plan, is charged with the responsibility of reestablishing sockeye salmon runs to historic areas with emphasis placed on efforts to utilize Stanley Basin sockeye salmon and kokanee O. nerka resources (IDFG 1992). Under ESA, NMFS Permit Nos. 795 and 823 authorize IDFG to conduct scientific research on listed Snake River salmon. In 1991, the SBT along with IDFG initiated the Snake River Sockeye Salmon Sawtooth Valley Project (Sawtooth Valley Project) with funding from Bonneville Power Administration (BPA). The goal of this program is to conserve and rebuild Snake River sockeye salmon populations in Idaho. Various elements of the recovery effort are already in progress. Coordination of this effort is carried-out under the guidance of the Stanley Basin Sockeye Technical Oversight Committee (TOC), a team of biologists representing the agencies involved in the recovery and management of Snake River sockeye salmon.

IDFG participation in the Sawtooth Valley Project falls under two general areas of effort: the sockeye salmon captive broodstock program and Stanley Basin O. nerka fisheries research. While objectives and tasks from both components overlap and contribute to achieving the same State goals, activities related to the captive broodstock program will appear under separate cover. In this report, we present information collected in 1994 efforts directed at Stanley Basin fisheries research. Specific activities covered include: Stanley Basin lake O. nerka population monitoring, Redfish and Alturas lake O. nerka smolt outmigration monitoring, Redfish Lake adult broodstock telemetry monitoring, Redfish Lake predator investigations, and otolith microchemistry analysis of wild and broodstock O. nerka.

The ultimate goal of IDFG sockeye salmon research and recovery is to reestablish sockeye salmon runs to Stanley Basin and provide for utilization of sockeye salmon and kokanee resources. The near term goal is to maintain Stanley Basin sockeye salmon through captive broodstock supplementation through one generation of captive breeding and rearing to prevent species extinction.

OBJECTIVES

Objective 1.0 To estimate O. nerka population in four Stanley Basin lakes to interpret population response to captive broodstock supplementation.

Task 1.1 Estimate total O. nerka population, density, and biomass by midwater trawl in Redfish, Alturas, Pettit, and Stanley lakes.

Task 1.2 Trawl sufficient to estimate population and density by age-class.

Task 1.3 Take scale and otoliths from all trawl captures. Preserve flesh and blood for genetic evaluation.

Objective 2.0 To evaluate emigration characteristics of O. nerka smolts at two Stanley Basin locations.

Task 2.1 Estimate total O. nerka outmigrant run size for Redfish and Alturas lakes. Coordinate trapping with SBT Biologists.

Task 2.2 PIT tag outmigrant O. nerka from Redfish and Alturas lakes. Determine trap efficiencies.

Task 2.3 Determine travel time and cumulative interrogation rates for PIT-tagged O. nerka smolts to lower Snake River dams.

Objective 3.0 To identify location and time of spawning for natural sockeye salmon production in Redfish Lake through adult broodstock outplants.

Task 3.1 Conduct ultrasonic tracking on 1993 and 1994 adult broodstock outplants to Redfish Lake.

Task 3.2 Evaluate in-lake performance differences for broodstock outplants from different genetic sources.

Task 3.3 Document movement patterns, habitat selection, and activities associated with spawning.

Objective 4.0 To determine predator effects on O. nerka in relation to recovery options.

Task 4.1 Conduct trap netting on Redfish Lake to determine the efficacy of this gear in capturing bull trout Salvelinus confluentus.

Objective 5.0 To determine the parental lineage of wild and broodstock O. nerka to interpret outmigration success of supplementation fish.

Task 5.1 Continue otolith microchemistry analysis of wild and broodstock O. nerka.

Task 5.2 Integrate otolith microchemistry and genetic data.

STUDY AREA

The Stanley Basin lakes are located within the Sawtooth National Recreation Area (SNRA) (Figure 1). Basin lakes are glacial-carved and receive runoff from the east side of the Sawtooth and Smoky mountains. Physical and morphometric data for Redfish, Alturas, Pettit, Stanley, and Yellow Belly lakes are presented in Table 1. All Basin lakes drain to the upper Salmon River which flows into the Snake River and ultimately the Columbia River. Redfish Lake is located approximately 1,450 river kilometers from the confluence of the Columbia River with the Pacific Ocean.

Fish species native to study area lakes and outlets include sockeye salmon/kokanee, spring-summer chinook salmon O. tshawytscha, rainbow trout/steelhead O. mykiss, westslope cutthroat trout O. clarki lewisi, bull trout, sucker Catostomus sp., northern squawfish Ptychocheilus oregonensis, mountain whitefish Prosopium williamsoni, redside shiner Richardsonius balteatus, dace Rhinichthys sp., and sculpin Cottus sp. Non-native species include lake trout S. namaycush, and brook trout S. fontinalis.

METHODS

Total Population, Density and Biomass Estimation

To estimate O. nerka population, density, and biomass, we conducted night midwater trawling on four Stanley Basin lakes during the dark (new) phase of the moon. Redfish and Alturas lakes were sampled one night each in June and in September 1994. Pettit and Stanley lakes were sampled one night each in September. We did not sample Yellow Belly Lake as it was not accessible to our trawl boat. Redfish Lake trawl activities are subject to the provisions of the ESA and fall under NMFS Permit No. 823. Modification No. 1 (Task 6) of this permit stipulates that no more than 65 juvenile O. nerka may be lethally taken by trawling.

We used a midwater trawl with a cross-sectional mouth area of 9.25 m^2 and a length of 13.7 m. Net mesh in the body decreased in four panels from 32 mm (stretch measure) to 13 mm; mesh in the cod end measured 3 mm. We towed the trawl with an 8.5 m boat at 1.0 m/s.

Trawling was performed in a stepped-oblique fashion after Rieman (1992). We used echo sounding prior to sampling to identify the fish layer. The trawl was first lowered to the bottom of the predetermined sampling layer and fished for approximately 5 min. We then raised the trawl to a new depth immediately above the previous depth and fished again for approximately 5 min. We repeated this procedure for each successive step until the entire layer containing targets had been sampled (one transect). We generally fished five transects per lake.

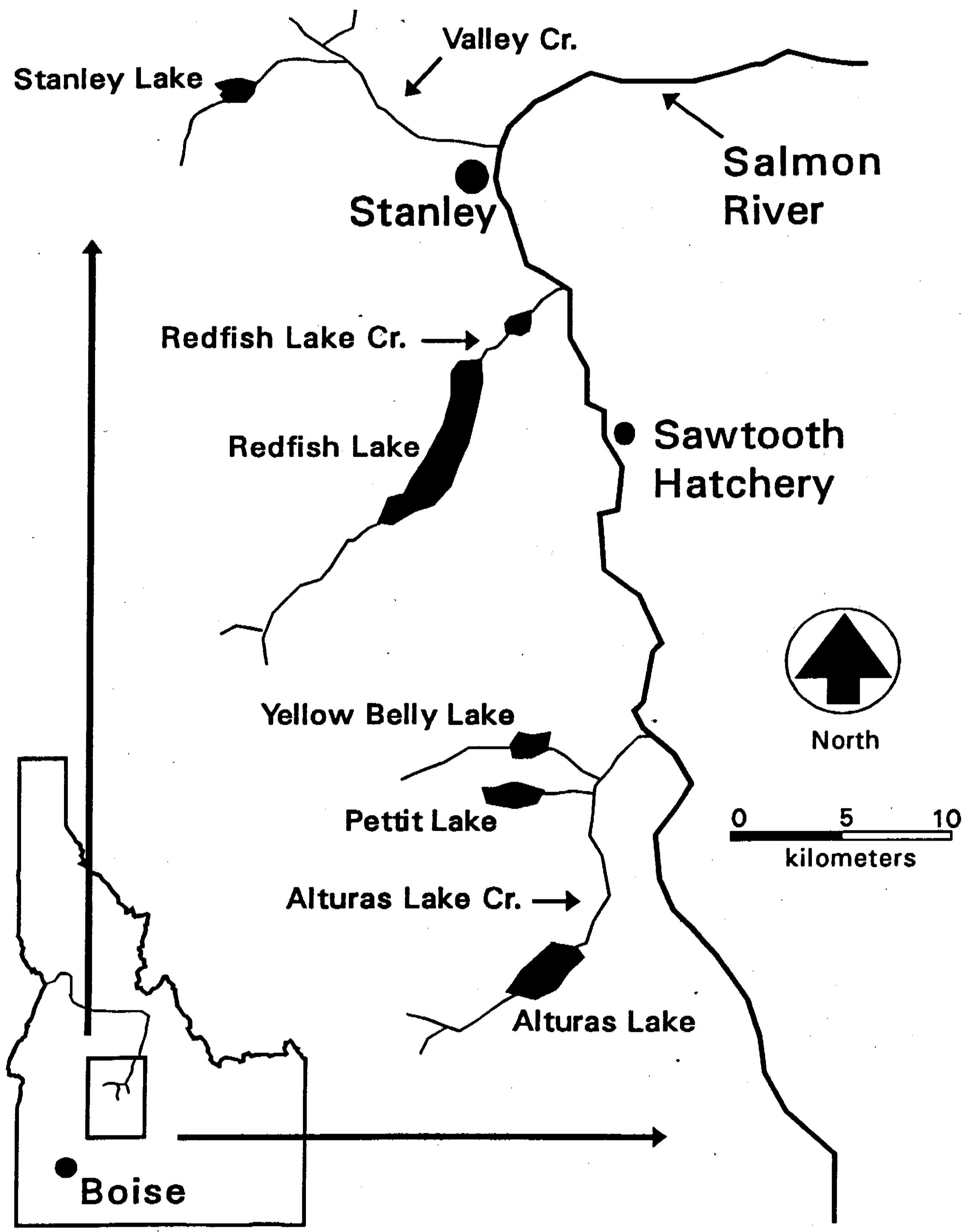

Figure 1. Stanley Basin study area map.

Table 1. Physical and morphometric characteristics of five Stanley Basin Lakes.

Lake	Area (ha)	Elevation (m)	Volume ($m^3 x 10^6$)	Mean depth (m)	Maximum depth (m)	Drainage area (km^2)
Redfish	615	1,996	269.9	44	91	108.1
Alturas	338	2,138	108.2	32	53	75.7
Pettit	160	2,132	45.0	28	52	27.4
Stanley	81	1,985	10.4	13	26	39.4
Yellow Belly	73	2,157	10.3	14	26	30.4

We estimated total O. nerka population, density, and biomass using the TRAWL.WK1 spreadsheet for Lotus 123 developed by Rieman (1992). Estimates represent an extrapolation of actual trawl catch data to the total area of the lake mid-depth in the observed O. nerka stratum as detected by echosounding. Whenever possible, we estimated population and density by individual age-class (assuming representation in the trawl).

We recorded fork length (to the lowest whole 10 mm group) and weight (to the nearest gram) for all trawl-captured O. nerka. Sagittal otoliths were removed from all trawl captures, cleaned, and stored dry in microcentrifuge tubes. We surface aged otoliths under transmitted and/or reflected light using a dissecting microscope. Tissue samples were collected and preserved for genetic analysis by NMFS and University of Idaho technicians. Stomachs were removed and preserved for diet analysis by SBT biologists.

Outmigrant Enumeration

To estimate O. nerka outmigrant run size from Redfish and Alturas lakes, IDFG personnel operated smolt traps on Redfish Lake Creek and on the upper Salmon River at the Sawtooth FH. Trap operations on Redfish Lake Creek are subject to the provisions of ESA and are permitted by NMFS. Under NMFS Permit No. 795 (Modification No. 3), IDFG is authorized to capture and PIT tag up to 4,500 juvenile Snake River sockeye salmon. Of these, up to 450 may be released above the trap site for purposes of trap efficiency estimation, and up to 450 may be retained and transferred to the IDFG Eagle FH sockeye salmon captive broodstock program. The number of outmigrants retained for use in the captive broodstock program may not exceed one-half of the total number of outmigrants captured during the collection period.

The outmigrant trap on Redfish Lake Creek is located approximately 1.4 km downstream of the lake outlet. In 1994, the trap was placed in operation on April 13 and remained in place until June 1. Five of nine trap bays were operated with incline bar trap boxes. Bar spacing allowed debris and large fish to pass downstream while small fish were captured in the low velocity trap boxes. The trap was checked twice daily by IDFG personnel.

The outmigrant trap on the Salmon River at the IDFG Sawtooth FH is located 2 kilometers upstream of the confluence of Redfish Lake Creek and the Salmon River. The floating scoop trap, equipped with a 1.0 m wide inclined traveling screen, is installed directly below the permanent weir at the Sawtooth FH as part of IDFG natural production monitoring studies (Kiefer and Forster 1991). A picket weir, 3.1 m wide at the mouth, funnels fish through the trap; pickets are spaced 3.8 cm apart. In 1994, the trap was operated continuously between March 8 and June 9 and was checked twice daily by IDFG personnel.

Outmigrant O. nerka captured at both trap sites were anesthetized in buffered MS222, measured for fork length (mm) and injected with PIT tags. Any trapping or PIT tagging related mortalities were frozen to facilitate subsequent tissue removal for disease and genetic analysis and for ageing. All tagged fish were held several hours in live boxes at the tagging sites prior to being released. We determined the trapping efficiency at both sites by releasing PIT-tagged fish upstream for subsequent recapture. We estimated total emigration or outmigration run size by summing the products of trap efficiency and daily trap catch for five intervals within the total period of outmigration. We constructed 90% confidence limits around our point estimate by transforming recapture proportions for the five intervals into arcsine data to approximate a normal distribution (Kiefer and Lockhart, in progress). We noted total PIT tag interrogations (minimum survival estimate) and time of arrival at lower Snake and Columbia River dams. PIT tag interrogation data was recovered from the Columbia River Basin PIT Tag Information System (PTAGIS), a branch of the Pacific States Marine Fisheries Commission.

Natural Spawning Investigations

Natural spawning characteristics were evaluated by release and subsequent tracking of O. nerka adults implanted with ultrasonic transmitters. Telemetry investigations of adult broodstock O. nerka released to Redfish Lake are subject to the provisions of ESA and are permitted by NMFS. In 1994, Permit No. 795 (Modification No. 3) allowed IDFG to implant ultrasonic transmitters (tags) in up to 60 adult O. nerka from the captive broodstock program and to conduct associated tracking and observation activities. The permit stipulated that no more than 20 of these fish could be progeny of the four anadromous sockeye salmon that returned to Redfish Lake as adults in 1991 (brood year 1991). In addition, no more than 40 fish could be outmigrants captured at the weir on Redfish Lake Creek between 1991 and 1993.

Releases of adult O. nerka from the captive broodstock program were initiated in 1993. In August of that year, 24 ultrasonic-tagged adults were released to Redfish Lake (Kline 1994). Several of these fish were still active at end of the 1993 tracking season. Prior to the commencement of 1994-release tracking, telemetry efforts focused on locating and determining the status of overwinter survivors from 1993.

In 1994, three adult broodstock releases were made to Redfish Lake. The first release (30 fish) occurred August 9 - 10 and incorporated O. nerka from three different broodstocks: 1) 11 adult progeny of the four anadromous sockeye salmon that returned in 1991 (brood year 1991), 2) two outmigrant 1992 adults captured at the Redfish Lake Creek weir in 1992 and reared at Eagle FH (outmigrant 1992), and 3) 17 outmigrant 1991 adults captured at the Redfish lake Creek weir in 1991 and reared at the Eagle facility (outmigrant 1993) (Appendix A). All brood year 1991 and outmigrant 1992 fish were fitted with ultrasonic transmitters. Eight of the outmigrant 1991 fish were fitted with ultrasonic transmitters. The second release (16 fish) occurred September 10 and consisted of nine brood year 1991 adult progeny and seven outmigrant 1991 adults (Appendix A). All fish in the second release group received ultrasonic transmitters. The third release occurred October 18 and consisted of 19 brood year 1992 residual O. nerka. These fish are the progeny of the beach-spawning residual component of Redfish Lake that were trapped over Sockeye Beach in 1992 for captive broodstock purposes. All of the residual broodstock releases were age 2+ males that matured earlier than their female counterpart. The absence of appropriate spawning partners necessitated their early release. None of the residual outplants were fitted with transmitters, however, each fish did receive an external tag to facilitate identification during subsequent snorkel investigations conducted in October and November, 1994.

We tested the hypothesis that end-of-season transmitter status would not differ between brood year 1991 and outmigrant 1991 release groups (χ^2 test of association, $\alpha = 0.10$). Ultrasonic tags were indexed at the end of the 1994 tracking effort as stationary, absent from the lake, or still active . We used ending transmitter status as an index of performance. Stationary and missing transmitters were pooled for both release groups to satisfy test assumptions related to cell size. We compared mean fork lengths and weights (two-tailed independent sample t-tests, $\alpha = 0.05$) and identified age differences between release groups prior to testing our hypothesis. Brood year 1992 outplants (N = 2) were not included in the analysis.

Tagging

We implanted transmitters in the Redfish Lake release groups on August 8 and September 8, 1994. Fish were individually anesthetized in a holding tank using buffered MS222, measured for fork length (to the nearest millimeter) and weighed (to the nearest gram). Tag implanting procedures were similar to those described by Winter (1989). We inserted ultrasonic tags through the mouth into the stomach with the aid of a plunger. We constructed the plunger by attaching a 15 cm length of solid (1/2 in diameter) PVC to a typical PVC "T" fitting that acted as a handle. A slight concave depression was made in the end of the solid length to cradle the tags during insertion. We lubricated the plunger with vegetable oil to slide smoothly through the gullet. All fish were held one to two days prior to release to ensure tag retention.

Tracking

Ultrasonic telemetry equipment was purchased through Sonotronics, Tucson, Arizona. Individual transmitter frequencies ranged from 70 to 76 Khz. Tag frequencies were coded with unique, self-identifying codes allowing several tags to be assigned the same tracking frequency. The tags were 65 mm long, 18 mm wide and weighed 22 g out of water. Fish were tracked by boat using a Sonotronics model USR-5W receiver with model DH-2-10 directional hydrophone. We used the point of maximum transmitter signal strength to indicate location. Individual fish locations were mapped on USGS 7½ topographic maps using triangulation with known shoreline landmarks. We assumed that landmarks, from which we took bearings, were mapped correctly. A global positioning system (GPS) was also used to record individual fish positions and to relocate individual fish on successive survey dates.

Predator Investigations

In 1994, we set six trap nets in Redfish Lake on October 19 and 20 to capture predatory fish and to determine their potential impact on the O. nerka population. Trapping predatory fish species in Redfish Lake is permitted under Consultation No. 110, term and condition No. 3 through NMFS. Trap nets consisted of a single mesh lead (1.9 cm bar mesh) followed by a 1.9 m by 0.9 m trap box and five 0.9 m diameter hoops with fixed throats on the first and third hoops. When set, each net measured 3.2 m in overall length (exclusive of the central lead). Net leads were secured to rebar posts on shore; cod ends were anchored with weights and marked by surface floats. We set trap nets perpendicular to the shore in water approximately 1.8 m to 2.0 m deep so that the top of each net frame was near the water surface. Nets were set in the north end of the lake and south of the Point Campground along the west shore (Figure 2). We fished each trap net overnight for 9 hr on both dates. Captured fish were identified, enumerated and released. All captured bull trout were anesthetized in buffered MS222, measured for fork length (to the nearest millimeter), and weighed (to the nearest gram). We collected scale samples from bull trout captures and were prepared to lavage the stomach contents of all bull trout and northern squawfish.

Parental Lineage Investigations

We used otolith microchemistry to improve our knowledge of the parental lineage of wild and broodstock O. nerka. In 1994, sagittal otoliths were removed from 66 individuals to increase our sample size of known lineage otoliths to better define equivocal results from past analyses. Samples were collected from the one anadromous female adult that returned to Redfish Lake in 1994, 54 broodstock progeny of the four anadromous adults that returned to Redfish Lake in 1991 (brood year 1991), and 11 broodstock progeny of the eight anadromous adults that returned to Redfish Lake in 1993 (brood year 1993). In all cases, otolith samples represented either direct anadromous life history (anadromous female adult) or F_1 lineage to female anadromous parents (Table 2). We hypothesized that Strontium/calcium (Sr/Ca) ratios from otolith nuclei of fish with known lineage to female anadromous parents would reflect marine life history.

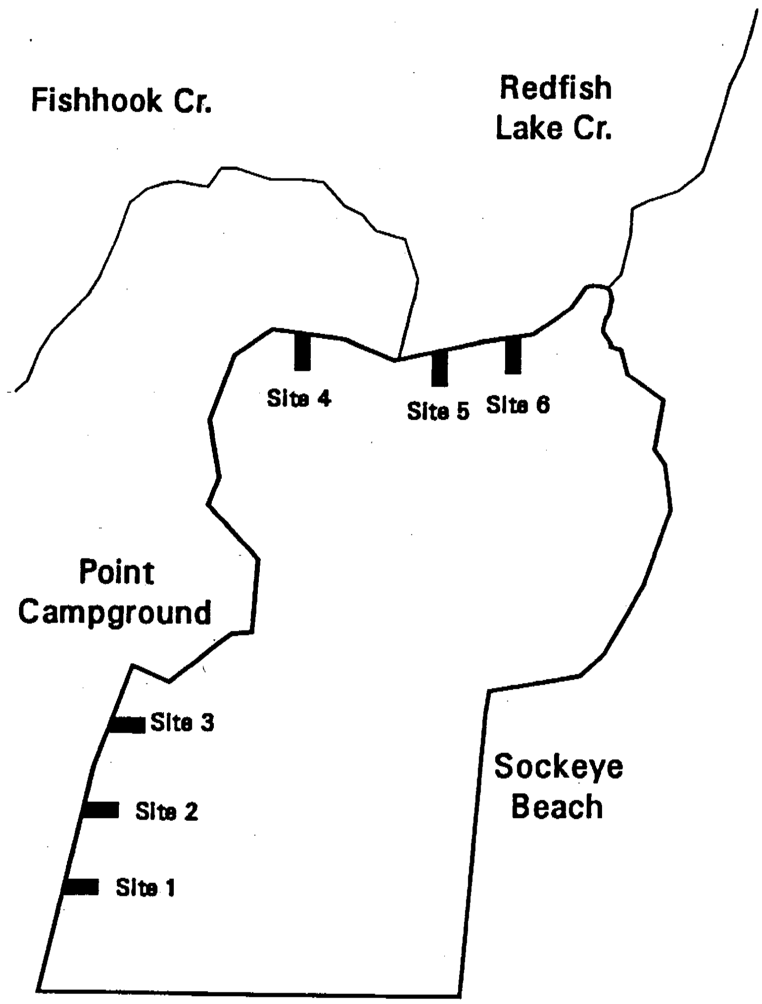

Figure 2. Location of Redfish lake trap net sampling, October 19-20, 1994

Table 2. Origin and number of *O. nerka* sagittal otoliths selected for 1994 microchemistry analysis.

	Origin	Number analyzed
1994 adult return[a]	unknown	1
Brood year 1991 progeny[b]	known (anadromous)	55
Brood year 1993 progeny[c]	known (anadromous)	11

[a] Adult female sockeye captured at the Redfish Lake Creek weir in 1994.

[b] Progeny of the four anadromous adults that returned to Redfish Lake in 1991 (1 female, 3 males).

[c] Progeny of the eight anadromous adults that returned to Redfish Lake in 1993 (2 females, 6 males).

Otoliths were collected from nine of the 54 brood year 1991 progeny and from the one anadromous adult following 1994 broodstock spawning activities at the Eagle FH. The remaining 45 brood year 1991 otoliths were collected from broodstock mortalities that occurred between May 5 and November 5, 1993. Brood year 1993 samples were collected from broodstock mortalities that occurred between February 16 and June 23, 1994. Otolith samples were cleaned of all associated tissue and stored dry in microcentrifuge tubes. Prior to preparing samples for analysis, we surface aged otoliths from the anadromous female adult using a dissecting microscope under reflected and/or transmitted light. It was not necessary to age otoliths from brood year fish.

Sample Preparation

The preparation of otoliths for microchemistry analysis followed techniques developed by Kalish (1990) and Rieman et al. (1993). Otoliths were cleaned in deionized water, dried, and mounted sulcus-side-down on glass slides with Crystal Bond 509 adhesive (Aremeco Products Inc.). Care was taken to insure that a relatively level mount was achieved. Using 600, then 1200 grit wet-dry sandpaper, we ground all otoliths in the sagittal plane to a level near the primordia. Sample slides were then heated (liquefying the Crystal Bond) and the otolith samples repositioned sulcus-side-up in the adhesive. We ground all samples in the sagittal plane to the approximate level of the primordia with 1200 grit wet-dry sandpaper. Final grinding was completed with 5.0 μ grit wet-dry paper. We finished all sample preparations by hand polishing with 1.0 and 0.05 μ alumina paste to remove all surface scratches left behind by the grinding process. All sample preparations were washed with deionized water, dried, and photographed at magnifications of 140X and 280X. Photographs were marked to identify locations selected for microanalysis.

Otolith samples from small fish (ages 0+ and 1+) were mounted sulcus-side-up in the adhesive. The grinding process for these samples began with 1200 grit wet-dry sandpaper. Final grinding and polishing followed the procedures outlined above.

Analysis

Otolith microchemistry analysis followed procedures outlined by Toole and Nielsen (1992). X-ray intensities of Sr and Ca were quantified using a Cameca SX-50 wavelength dispersive electron microprobe (Oregon State University, College of Oceanography, Corvallis, OR 97331-5503). Samples were washed with deionized water, dried, and coated with a 200 A carbon layer for surface conductivity. A 15 KV, 50 nA, and 7 μ electron beam was used for all analyses. Microprobe transects were run in otolith nuclei adjacent to the primordia for all samples. Ten microprobe sites were analyzed along each transect.

RESULTS

Total Population, Density, and Biomass Estimation

Population, density, and biomass results presented in this section of the report incorporate IDFG data from 1990 through 1994, where available. All reference to age-class segregation is from length-frequency interpretation based on direct sagittal otolith aging of sampling mortalities. June, 1994 trawl data from Redfish and Alturas lakes were not used to estimate spring O. nerka population as sample sizes were not sufficient to yield reliable estimates.

Redfish Lake

During the September 6 trawl of Redfish Lake, the majority of O. nerka targets were stratified in the limnetic zone between 9.0 m and 24 m of depth. Our September trawl catch consisted entirely of O. nerka. We estimated the total Redfish Lake O. nerka population at 51,529 fish (95% CI, ± 33,179). Total O. nerka density and biomass was estimated at 125 fish/hectare (± 81) and 2.1 kg/hectare, respectively (Table 3). Sixty percent of the total O. nerka catch consisted of age 0+ fish while 11% and 29% were age 1+ and 2+ fish, respectively (Table 4; 5). No age 3+ or older fish were captured in the September trawl. Age 0+, 1+, and 2+ fish averaged 49.0 mm, 89.6 mm, and 163.2 mm in fork length, respectively (Figure 3). Mean weights for these age-classes were 1.3 g, 8.3 g, and 51.1 g, respectively (Appendix B).

Alturas Lake

O. nerka comprised 100% of the September, Alturas Lake trawl catch. Fish were stratified between 11 m and 28 m of depth although targets were visible to 38 m. Deeper targets (28 m - 38 m) did not exhibit a pattern of stratification and were not sampled during our September survey. We estimated the total Alturas Lake O. nerka population to be 5,785 fish (± 6,919). The total density of the September population was estimated at 27 fish/hectare (± 33). We estimated the total O. nerka biomass to be 0.7 kg/hectare (Table 3). Age-classes 2 and 3 comprised the entire catch and were equally represented in the trawl. Because fork lengths for both age-classes overlapped, we did not estimate population or density by age-class (Figure 3). Intuitively, these data suggest the estimated O. nerka population of Alturas Lake consists of approximately equal numbers of age 2+ and 3+ fish. Fork lengths of age 2+ and 3+ trawl captures averaged 131.7 mm (range 125 mm to 139 mm) and 140.2 mm (range 137 mm to 146 mm), respectively. Mean weights of age 2+ and 3+ fish averaged 21.8 g and 27.9 g, respectively (Appendix B).

Pettit Lake

Pettit Lake fish targets were tightly stratified between 11 m and 22 m in depth during our September 8 survey. The majority of the fish captured were O. nerka, although one redside shiner was captured during the survey. The total population estimate for Pettit Lake was 14,743 fish (± 3,683). We estimated total O. nerka density and biomass at 128 fish/hectare (± 32) and 4.4 kg/hectare, respectively (Table 3). Age-classes 0 through 3 were represented in the trawl with age 1+ fish comprising the majority (46%) of the sample (Table 4; 5). Mean fork lengths for age-classes 0 through 3 were 40.5 mm, 135.7 mm, 154.0 mm, and 251.0 mm, respectively (Figure 3). We recorded mean weights of 0.7 g, 31.2 g, 47.4 g, and 251.6 g, for these same groups, respectively (Appendix B).

Stanley Lake

The majority of limnetic targets observed during our September 6 survey of Stanley Lake were loosely stratified between the lake surface and 16 m in depth. Larger, unstratified, targets (that we did not attempt to sample) were noted below our identified fish layer and immediately above the lake bottom. Sixty-two percent of the total catch consisted of O. nerka; the remainder of the catch (38%) consisted of redside shiners. We estimated the total September O. nerka population of Stanley Lake to be 2,695 (± 963) fish. Total density and biomass

Table 3. Estimated total population, density (fish per hectare), and biomass (kilograms per hectare) for *O. nerka* in four Stanley Basin lakes.

Lake	Date	Total Population (± 95% C.I.)	Density (± 95% C.I.)	Biomass
Redfish	9/06/94	51,529 (±33,179)	125.1 (±80.1)	2.11
Redfish	9/17/93	49,628 --[a]	120.4 --[a]	2.34
Redfish	9/29/92	39,481 (±10,767)	95.9 (±26.1)	1.46
Redfish	8/20/90	24,431 (±11,000)	63.9 (±26.6)	1.30
Alturas	9/07/94	5,785 (±6,919)	27.1 (±33.6)	0.68
Alturas	9/17/93	49,037 (±13,175)	230.2 (±61.9)	4.12
Alturas	9/25/92	47,237 (±61,868)	222.8 (±291.8)	3.86
Alturas	9/08/91	125,045 (±30,708)	594.0 (±144.8)	6.33
Alturas	8/19/90	126,644 (±31,611)	597.0 (±154.0)	5.20
Pettit	9/08/94	14,743 (±3,683)	128.2 (±32.0)	4.40
Pettit	9/18/93	10,511 (±3,696)	101.0 (±33.9)	1.09
Pettit	9/27/92	3,009 (±2.131)	26.2 (±18.5)	3.50
Stanley	9/07/94	2,694 (±913)	36.9 (±12.5)	0.49
Stanley	9/16/93	1,325 (±792)	18.9 (±11.3)	0.57
Stanley	8/28/92	2,117 (±1,592)	29.0 (±21.8)	0.27

[a] Confidence limits not calculated - single transect estimate.

Table 4. Numbers of O. nerka by age-class, estimated from fall midwater trawls on four Stanley Basin lakes, 1990-1994. Values in parenthesis are 95% confidence limits.

Lake	0+	I+	II+	III+	IV+
Redfish 1994	30,449 (±25,780)	5,856 (±8,867)	15,224 (±18,884)	0 0	0 0
Redfish 1993	26,120 ---[a]	7,836 ---	15,672 ---	0 ---	0 ---
Redfish 1992	22,954 (±4,899)	5,509 (±8,415)	3,213 (±4,002)	3,902 (±1,655)	3,902 (±1,665)
Redfish 1990	10,048 (±7,308)	8,808 (±5,288)	3,338 (±2,595)	2,237 (±2,261)	0 0
Alturas 1994	0	0	5,785[b] (±6,919)		0
Alturas 1993	0 0	1,226 (±1,501)	39,842 (±12,412)	7,969 (±4,157)	0 0
Alturas 1992	0 0	1,377 (±2,368)	11,912 (±22,280)	32,667 (±57,612)	1,281 (±2,561)
Alturas 1991	5,556 (±1,657)	67,217 (±20,999)	48,569 (±22,146)	3,702 (±2,965)	0 0
Alturas 1990	39,065 (±17,888)	12,126 (±6,325)	55,439 (±28,284)	15,075 (±6,324)	4,948 (±2,850)
Pettit 1994	4,095 (±1,930)	6,826 (±2,730)	3,276 (±1,392)	546 (±668)	0 0
Pettit 1993	10,511 (±3,696)	0 0	362 (±725)	362 (±725)	362 (±725)
Pettit 1992	0 0	0 0	0 0	0 0	3,009 (±2,131)
Stanley 1994	2,087 (±796)	606 (±448)	0 0	0 0	0 0
Stanley 1993	0 0	714 (±516)	103 (±206)	509 (±565)	0 0
Stanley 1992	0 0	1,902 (±1,533)	0 0	215 (±429)	0 0

[a] Confidence limits not calculated-single transect estimate.

[b] Alturas Lake population estimate not partitioned by age-class.

Table 5. Densities of *O. nerka* (fish per hectare) by age-class, estimated from fall midwater trawls on four Stanley Basin lakes, 1990-1994. Values in parenthesis are 95% confidence limits.

Lake	0+	I+	II+	III+	IV+
Redfish 1994	73.9 (±62.2)	14.2 (±21.5)	37.0 (±45.8)	0 0	0 0
Redfish 1993	63.4 ---[a]	19.0 ---	0 ---	38.0 ---	0 ---
Redfish 1992	55.7 (±11.8)	13.4 (±20.4)	7.8 (±9.7)	9.5 (±4.0)	9.5 (±4.0)
Redfish 1990	26.3 (±19.7)	23.1 (±14.6)	8.7 (±7.1)	5.9 (±7.2)	0 0
Alturas 1994	0	0 (±33.6)	27.1[b]	0	
Alturas 1993	0 0	5.7 (±7.0)	187.1 (±58.3)	37.4 (±19.5)	0 0
Alturas 1992	0 0	6.5 (±11.2)	56.2 (±105.1)	154.1 (±271.8)	6.0 (±12.1)
Alturas 1991	26.2 (±7.8)	317.1 (±99.0)	229.1 (±104.5)	17.5 (±13.9)	0 0
Alturas 1990	184.3 (±82.4)	57.2 (±30.8)	261.5 (±122.0)	71.1 (±31.3)	23.3 (±13.4)
Pettit 1994	35.6 (±16.8)	59.4 (±23.7)	28.5 (±12.1)	4.8 (±4.9)	0 0
Pettit 1993	91.4 (±32.1)	0 0	3.2 (±6.3)	3.2 (±6.3)	3.2 (±6.3)
Pettit 1992	0 0	0 0	0 0	0 0	26.2 (±18.5)
Stanley 1994	27.8 (±10.8)	7.9 (±6.1)	0 0	0 0	0 0
Stanley 1993	0 0	10.2 (±7.4)	1.5 (±3.0)	7.3 (±8.1)	0 0
Stanley 1992	0 0	26.1 (±21.0)	0 0	2.9 (±5.9)	0 0

[a]Confidence limits not calculated-single transect estimate.
[b]Alturas Lake density estimate not partitioned by age-class.

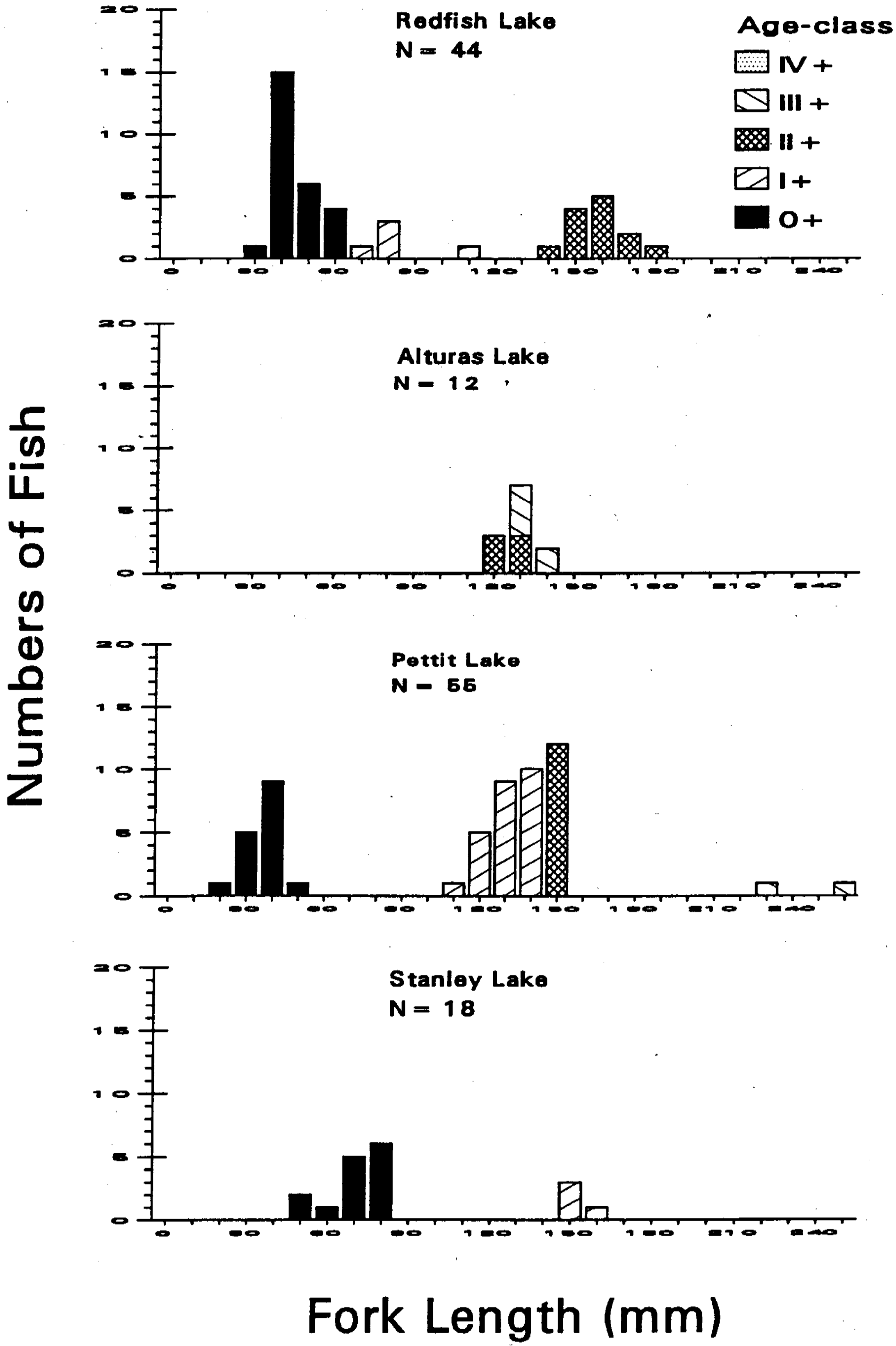

Figure 3. Length-frequency distributions from September 1994 midwater trawls of four Stanley Basin Lakes

were estimated at 37 fish/hectare (± 13), and 0.5 kg/hectare, respectively (Table 3). Age 0+ and 1+ fish comprised the entire O. nerka catch (78% and 22%, respectively) (Tables 4; 5). Mean fork lengths for age-classes 0 and 1 were 75.4 mm and 155.3 mm, respectively (Figure 3). Mean weights for these two age-classes were 5.2 g and 41.5 g, respectively (Appendix B).

Trawl Data Corrections

We discovered a calculation error in Pettit Lake population estimates for 1992 and 1993. The correction affects the estimates reported by Kline (1994). Revised estimates of total population, density, and biomass as well as population density by age-class are presented in this report.

An ageing error was also identified in the 1993 Redfish Lake population and density estimates reported by Kline (1994). Revised estimates, based on re-ageing 1993 samples and reviewing SBT Fishhook Creek spawner ages, are presented in this report.

Outmigrant Enumeration

Redfish Lake Creek Trap

We trapped a total of 722 O. nerka outmigrants at the Redfish Lake trap site in 1994. As no anadromous adults have had access to Redfish Lake since 1989, these fish were progeny of the beach-spawning and creek-spawning stocks of Redfish Lake O. nerka. Trap captures occurred between April 19 and June 1 with peak emigration taking place the first week of May (Figure 4). Outmigration occurred primarily during night hours. The mean fork length of 1994 outmigrants was 96 mm.

We recorded five mortalities (0.7%) associated with netting and handling; there were no mortalities associated with PIT tagging. We determined the age of all trap mortalities as 1+. We estimated trapping efficiency at 39.6% for the Redfish Lake Creek site in 1994. Based on this efficiency, we estimated outmigrant run size at 1,820 (90% CI, 1,229 - 2,671) O. nerka.

Median travel times to lower Snake and Columbia River dams and detection rates at four facilities with PIT tag interrogation systems (Lower Granite [LGrD], Little Goose [LGoD], Lower Monumental [LMoD], and McNary [NcN] dams) are presented in Table 6. Median travel time to LGrD was 12.0 d in 1994. One hundred fifty-one detections were noted, from the release group of 717 PIT-tagged fish, at one of these downstream facilities yielding a cumulative interrogation rate of 21%. This number represents in-river minimum survival through McN dam and only documents the number of fish successfully diverted through and detected by the interrogation systems. It does not account for fish that avoid interrogation systems by successfully negotiating turbines or passing projects via spillways or locks.

Nine outmigrant chinook salmon smolts were intercepted at the Redfish Lake Creek trap in 1994. These fish were presumably the progeny of the one female and two male adult chinook salmon that were passed upstream of the adult weir on Redfish Lake Creek in 1992. Chinook salmon spawn in the lower reaches of Fishhook Creek. However, juvenile chinook salmon could migrate to areas upstream of the trap site from downstream locations and result as trap captures as they outmigrate. The extent to which the latter occurs is unknown. All captured juvenile chinook salmon were netted to facilitate identification and immediately released back to Redfish Lake Creek.

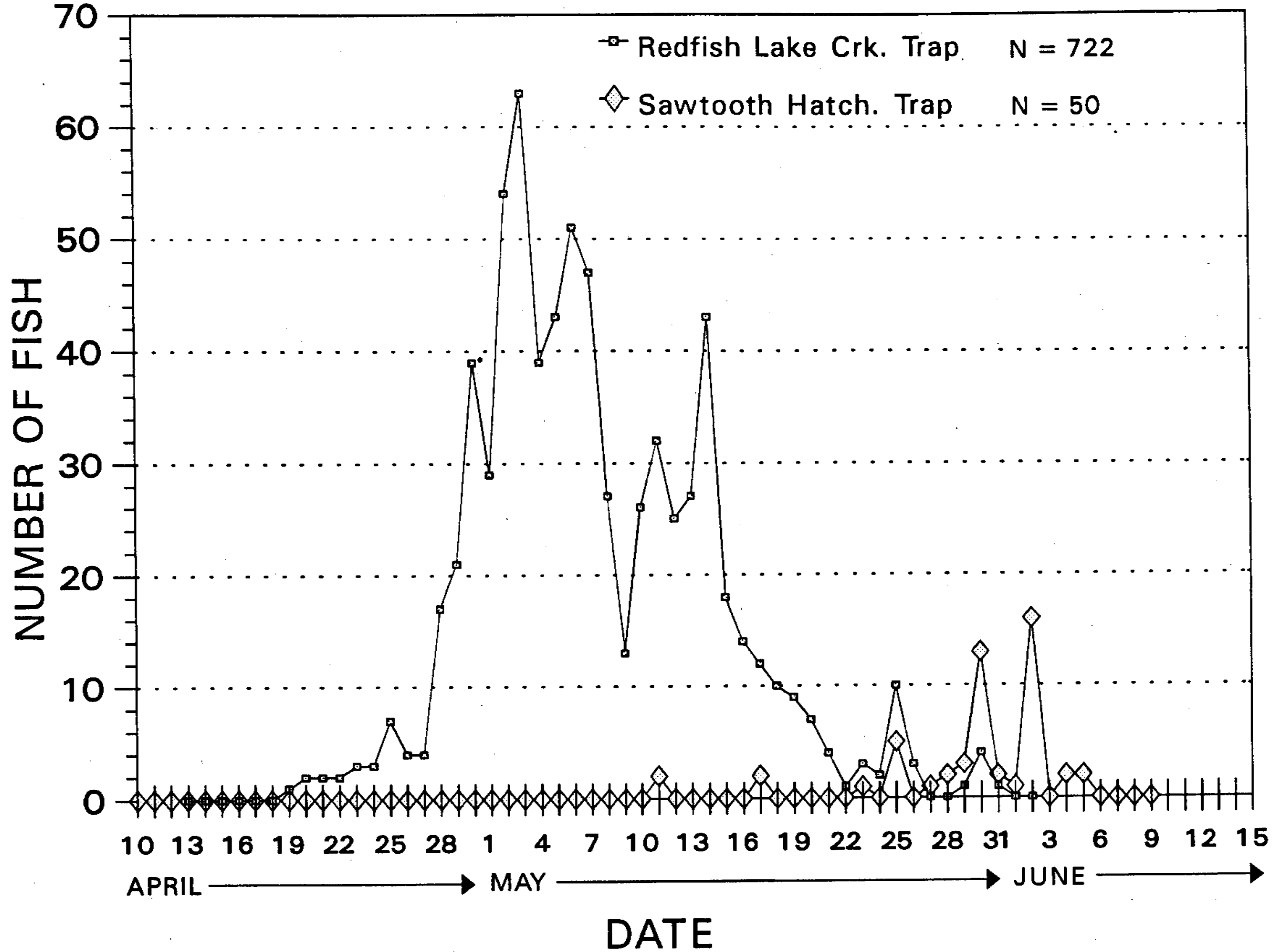

Figure 4. O. nerka outmigrant trap records for Redfish Lake Creek and Sawtooth Hatchery, 1994.

Table 6. Median travel times and downstream detection rates for PIT-tagged _O. nerka_ outmigrants released from Redfish Lake Creek in 1994.

Detection Location	Number of fish detected	Travel time (d)
Lower Granite Dam	38	12.0
Little Goose Dam	49	16.7
Lower Monumental Dam	32	21.5
McNary Dam	33	21.5
Total Detections	151	

Total number of PIT-tagged _O. nerka_ released = 717

Total detection rate = 21%

Sawtooth Hatchery Trap

We trapped a total of 50 _O. nerka_ at the Sawtooth FH outmigrant trap in 1994. We assumed that all fish were outmigrants of Alturas Lake. Alturas Lake outmigrants are progeny of adult _O. nerka_ that spawn in the lake inlet. No anadromous adults have returned to Alturas Lake since the late 1980's. Trap captures were recorded between May 11 and June 5, 1994 with peak outmigration occurring around the end of May. The mean fork length of Alturas Lake outmigrants was 104 mm. We recorded no trapping, handling, or PIT-tagging related mortalities. As a result, we did not age any 1994 Alturas Lake outmigrants.

Due to the low number of intercepted _O. nerka_, the trap efficiency estimate for chinook salmon (5.5%) was used to estimate _O. nerka_ run size (Kiefer and Lockhart, in progress). Based on this efficiency, we estimated 1994 Alturas Lake outmigrant run size at 945 (90% CI, 331 - 13,000) fish.

None of the 50 PIT-tagged Alturas Lake outmigrants were intercepted in 1994 at any of the downstream dam projects with detection capabilities.

Natural Spawning Investigations

Tracking of 1993 Release Groups

We discontinued 1993 Redfish Lake tracking efforts on December 2. At that time, three transmitters (12.5% of the original release group of 24 fish) had been recovered after ejection by or death of the host fish and eight transmitters (33.3%) were no longer emitting in-lake signals (e.g., were not audible during tracking). Thirteen transmitters (54.2%) were still producing in-lake signals; five of which were stationary while eight were still active (Kline 1994).

We initiated 1994 tracking on May 12. Twelve of the 13 in-lake signals we recorded on December 2, 1993 were located on the first 1994 survey date. One of these tags was recovered in shallow water just south of the Point Campground increasing the number of recovered (1993 release group) tags to four. Following the second tracking date (May 19), we determined that three of the 1993-release fish had over-wintered and were still active. We noticed no pattern of distribution or site selection by these fish until the seventh tracking survey (July 28) when we recorded one fish in the same location (near the mouth of Fishhook Creek) on two successive dates. Subsequent tracking surveys, however, recorded no further movement by this fish. This particular tag was not recovered and remained stationary in approximately 12 m of water for the duration of the 1994 tracking effort. No carcass was observed or recovered near this tag. The remaining two 1993-release fish remained active through the duration of the 1994 tracking effort. No observations of further site selection or fidelity were recorded for these fish.

Tracking of 1994 Release Groups

There was a relatively sharp rate of attrition in the initial number of in-lake transmitter signals following the two releases of ultrasonic-tagged fish on August 9 - 10 and September 10, 1994. As early as the first tracking survey following both release dates, five of the 21 fish released August 9 - 10 and two of the 16 fish released September 10 were not located. Subsequent surveys failed to locate these tags. Following the second tracking survey, eight and five transmitter signals, respectively, were not located. We did, however, locate two fish missing the second survey on subsequent survey dates.

We were unable to identify any clear pattern of fish distribution during the 1994 telemetry effort. No consistent assemblages of individual fish or association with specific lake regions were observed from week to week. With very few exceptions, we recorded active fish in new locations on each survey date.

No observations of sustained site selection or fidelity with areas of known or suspected lake spawning activity were made in 1994. Snorkel and boat surveys of beach spawning areas conducted in October and November were unsuccessful in recording any observations of pairing or spawning for either 1994 broodstock releases or for the two surviving 1993 outplants. No observations of the 19 brood year 1992 residual outplants were recorded during October and November snorkel and boat surveys of known and suspected spawning locations.

We recovered three (8.1%) of the 37 transmitters implanted in broodstock outplants in 1994 (Table 7). One transmitter was recovered from a carcass September 9 in 1 m deep water near the southwest shore of the lake. Subsequent tag identification and carcass inspection identified this individual as a brood year 1991 female. We observed no indication that this fish had spawned based on the large number of eggs present in the body cavity. This individual represents our only known mortality within the 1994 release groups as the other two recovered tags were not associated with carcasses.

At the termination of 1994 tracking efforts on November 22, 12 of the 37 transmitters (32.4%) implanted in 1994 were not emitting signals from Redfish Lake (Table 7). Eight of these transmitters had been implanted in brood year 1991 progeny. Three and one of these transmitters had been implanted in outmigrant 1991 and 1992 fish, respectively. Twenty-two of the 37 transmitters were emitting in-lake signals on the final day of tracking (Table 3). Eleven of these signals (29.7%) were stationary and had been for a minimum of three consecutive tracking dates. The remaining 11 transmitter signals (29.7%) were still active. Of the 11 stationary transmitters, seven and four had been implanted in brood year 1991 progeny and outmigrant 1991 fish, respectively. Eight and three of the active transmitters had been implanted in outmigrant 1991 fish and brood year 1991 progeny, respectively.

A significant difference was found between mean fork lengths (t = 3.353, P = .002) and weights (t = 2.291, P = .028) of outmigrant 1991 and brood year 1991 adult broodstock fish implanted with ultrasonic transmitters. Outmigrant 1991 and brood year 1991 broodstock outplants averaged 579 g and 538 g in weight and 2,916 mm and 2,443 mm in fork length, respectively. Outmigrant 1991 fish were also approximately 2 years older than brood year 1991 fish. We detected a significant difference in the final transmitter status of release groups (χ^2 = 4.953, P = .026) with respect to our comparison of the number of fish with stationary and missing transmitter status compared to active status at the end of the tracking effort.

Predator Investigations

We captured 167 fish in 96 hr of trap netting on Redfish Lake. The total catch per unit effort (CPUE) was 1.74 fish per trap net hour for the two night survey (Table 8). Mountain whitefish comprised the majority of the catch (65.8%). Northern squawfish and bull trout represented 4.2% and 2.4% of the total catch, respectively. Redside shiners, mountain suckers, brook trout, and O. nerka comprised the remainder of the catch. Of these four species, redside shiners were the most prevalent representing 18.0% of the total catch.

Bull trout fork lengths ranged from 120 mm to 288 mm; all northern squawfish captured during the survey were less than 190 mm in fork length. We did not attempt to lavage the stomach contents of these two species as we felt, due to their small size, they would not withstand the procedure.

Table 7. Final status of ultrasonic tagged O. nerka at the end of the 1994 tracking effort (November 23, 1994).

Tag Frequency[a]	Lineage[b]	Status[c]
97	OM91	ACTIVE
266	OM91	ACTIVE
366	OM91	ACTIVE
473	OM91	ACTIVE
2237	OM91	ACTIVE
2354	OM91	ACTIVE
2363	OM91	ACTIVE
2543	OM91	ACTIVE
13-3	OM91	ABSENT
455	OM91	ABSENT
2435	OM91	ABSENT
464	OM91	RECOVERED
2228	OM91	STATIONARY
2345	OM91	STATIONARY
2633	OM91	STATIONARY
14-2	OM92	ABSENT
356	OM92	STATIONARY
10-6	BY91	ACTIVE
365	BY91	ACTIVE
555	BY91	ACTIVE
11-5	BY91	ABSENT
12-4	BY91	ABSENT
239	BY91	ABSENT
248	BY91	ABSENT
446	BY91	ABSENT
3335	BY91	ABSENT
3344	BY91	ABSENT
3434	BY91	ABSENT
338	BY91	RECOVERED
2426	BY91	RECOVERED
88	BY91	STATIONARY
285	BY91	STATIONARY
293	BY91	STATIONARY
347	BY91	STATIONARY
374	BY91	STATIONARY
554	BY91	STATIONARY
2273	BY91	STATIONARY

[a] Frequency of the ultrasonic transmitter implanted in the fish

[b] OM91 = 1991 Redfish Lake outmigrants. OM92 = 1992 Redfish Lake outmigrants. BY91 = progeny of 1991 anadromous adults.

[c] ACTIVE = the transmitter signal is audible and the fish is still moving.
ABSENT = the transmitter signal is no longer audible.
STATIONARY = the transmitter signal is audible, but is not moving.
RECOVERED = the transmitter has been recovered from the lake.

Table 8. Relative species composition and catch rates for six trap net locations in Redfish Lake, October 26-27, 1994.

		Species Composition[a] (Numbers of Fish)							
Site	Hours Fished	MW	RS	MS	NS	BLT	BKT	HRS	WRS
1	16	0	9	7	4	3	1	0	1
2	16	0	3	2	3	0	0	0	0
3	16	0	0	0	0	0	0	0	0
4	16	62	18	0	0	1	1	1	0
5	16	7	0	0	0	0	0	0	0
6	16	41	0	0	0	0	1	2	0
TOT.	96	110	30	9	7	4	3	3	1
Species CPUE[b]		1.15	0.31	0.09	0.07	0.04	0.03	0.03	0.01
% Species comp[c]		65.8	18.0	5.4	4.2	2.4	1.8	1.8	0.6

Total CPUE = 1.74

Total fish captured = 167

[a] MW = mountain whitefish; RS = redside shiner
MS = mountain sucker; NS = northern squawfish
BLT = bull trout; BKT = brook trout
WRS = wild residual sockeye; HRS = hatchery residual sockeye

[b] Catch per unit effort (CPUE) expressed as the number of fish caught per trap net hour.

[c] Percent composition of the total catch by species.

One wild residual O. nerka was captured on the first night of trapping (October 19) at Site 1 just south of the Point Campground (Figure 2). This individual exhibited signs of maturation relative to body coloration. We estimated this fish to be approximately 240 mm in fork length and released it unharmed. We captured three of the 19 residual broodstock outplant O. nerka released from the captive broodstock program the previous day, October 18. One of these fish was captured the first night of trapping (October 19) while two were captured the second night (October 20). These fish are the progeny of wild residual O. nerka captured over Sockeye Beach in 1992 for inclusion in the captive broodstock program at Eagle FH.

NMFS authorized an incidental non-lethal take (capture and release) of at most one anadromous or residual sockeye salmon during this investigation. The terms and conditions of their Biological Opinion specified that we were to discontinue all trap net sets if any O. nerka were captured. Following the capture of one wild residual and one broodstock O. nerka on the first night of trap netting, we contacted the NMFS Environmental and Technical Services Division to inform them of our situation. All factors considered (e.g. effort expended, non-lethal capture and release), a second night of trap net sets was authorized with the proviso that any additional captures would terminate the project. As discussed, the second night of fishing resulted in the capture of two broodstock outplants. We then informed NMFS that we were discontinuing the effort.

Parental Lineage Investigations

We determined the age of the adult female that returned to Redfish Lake in 1994 to be 4+ years. Nuclear Sr/Ca ratios recorded for this individual represented direct lineage to an anadromous female parent (brood year 1989). Individual microprobe site Sr/Ca ratios ranged from 0.0012 to 0.0017. Two of the ten individual Sr/Ca ratios fell below 0.0014; the lowest observed mean ratio for Redfish Lake O. nerka of known lineage to female anadromous parents (Rieman et al. 1993). The mean Sr/Ca ratio for the one otolith sample was 0.0015 (CV 0.10) (Figure 5).

Otolith samples from brood year 1991 and anadromous brood year 1993 broodstock progeny represent known life history. All samples were collected from progeny of the anadromous adults that returned to Redfish Lake in 1991 and 1993, respectively. Individual site Sr/Ca ratios from otolith nuclei of brood year 1991 progeny ranged from 0.0014 to 0.0023. Mean Sr/Ca ratios ranged from 0.0017 to 0.0021 (CV 0.03 to 0.10) (Figure 5). Individual site Sr/Ca ratios from otolith nuclei of anadromous brood year 1993 progeny ranged from 0.0005 to 0.0024. Mean Sr/Ca ratios ranged from 0.0008 to 0.0018 (CV 0.05 to 0.18) (Figure 5). Seven of the 11 brood year 1993 samples yielded mean, nuclear Sr/Ca ratios greater than 0.0014. Four of the samples generated mean, nuclear Sr/Ca ratios between 0.0008 and 0.0014.

DISCUSSION

Total Population, Density, and Biomass Estimation

Trawl data from 1994 represents the fifth consecutive year of IDFG Stanley Basin lake O. nerka investigation. Data collected from these efforts has increased our understanding of O. nerka population trends in Stanley Basin lakes. These data will become increasingly important as we begin to evaluate system response to future captive broodstock introductions.

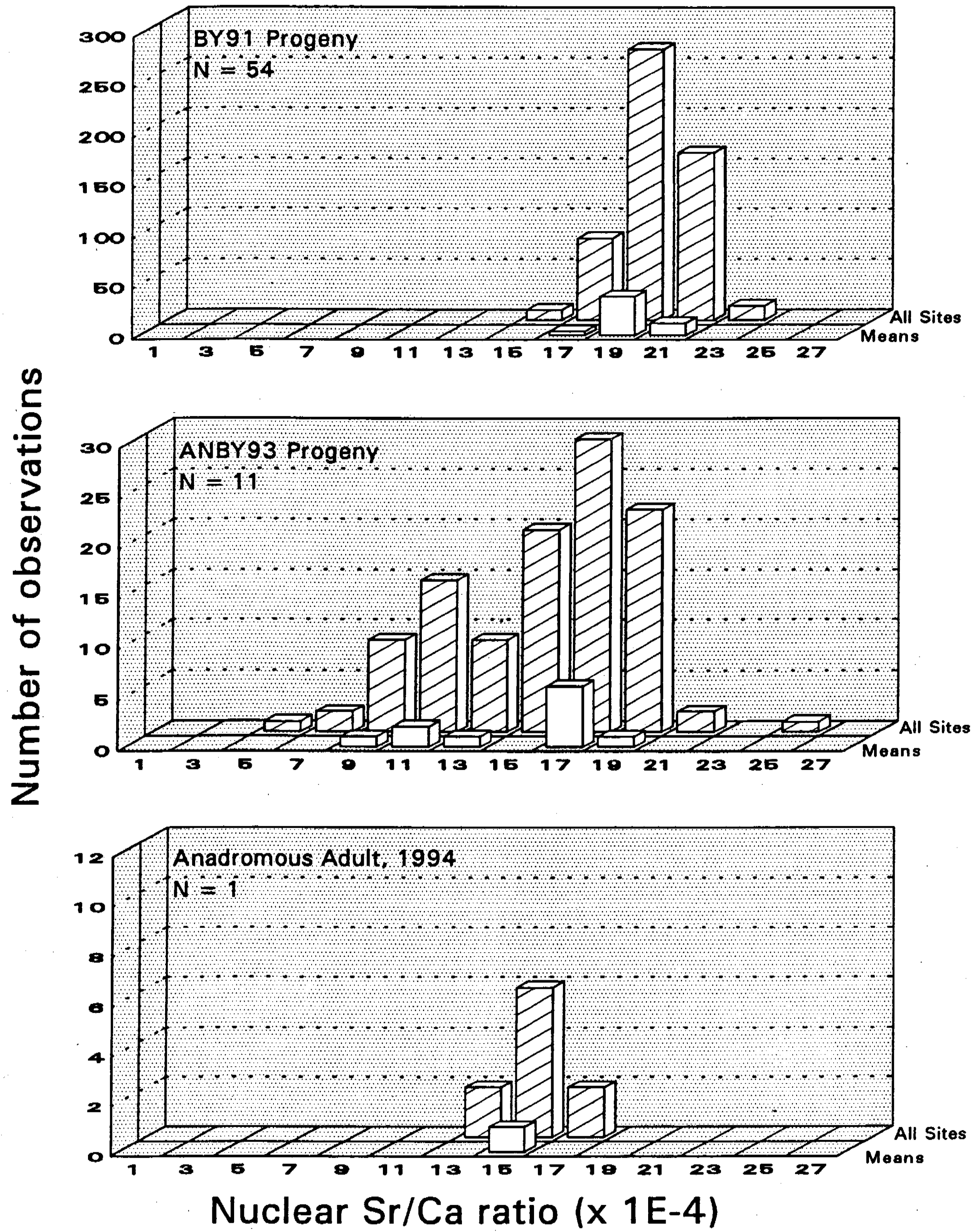

Figure 5. Frequency distributions of individual sites and mean Sr/Ca ratios measured in otolith nuclei from Redfish Lake O. nerka with differing life histories. ANBY93 = progeny of 1993 anadromous adult returns. BY91 = progeny of 1991 anadromous adult returns.

Redfish Lake

Estimates of the total O. nerka population in Redfish Lake have increased by over 100% since 1990. The estimated September O. nerka population in 1994 increased by approximately 4% over the September estimate for the previous year. These data are consistent with fry recruitment data collected by the SBT in 1993 and 1994 (TOC Minutes - September 1993; 1994). Although 1994 kokanee recruitment to Redfish Lake decreased by approximately 12.5% (140,000 vs 160,000 fish), the relatively high percentage of age 0+ fish (59%) captured in the September trawl is directly attributable to this level of recruitment.

Total density estimates for Redfish Lake O. nerka have remained at or above 120 fish/hectare for the past two years. These densities represent an increase of approximately 100% over the density estimate recorded in 1990. The total biomass or standing crop increased by approximately 68% during this same time period. Considering this trend, we have not observed a negative population response in fish growth that would be expected if the population was near or beyond the lake's carrying capacity. Ricker (1937) suggested that little density dependent effect is generally visible until an upper threshold density is reached. To date, we have observed very little variation in length-at-age among Redfish Lake year-classes. Our data suggest that present densities are below the threshold where declines in growth would begin to occur with increasing density.

An estimated 9,000 adult kokanee spawned in Fishhook Creek in 1994. This number represents a decrease of approximately 16% from the estimated escapement for 1993 (9,000 vs 10,800 fish) (TOC Minutes -October 1994). Intuitively, these data suggest that 1995 kokanee recruitment to Redfish Lake should be similar to the level observed in 1994. Beaver dam construction in lower Fishhook Creek, however, increased in 1994 and may have restricted access to preferred spawning locations. Although kokanee were observed above the primary dam, the majority of individuals were restricted to spawning habitat below the barrier. The extent to which this and other potential spawning habitat limitations govern Redfish Lake kokanee recruitment has not been quantified.

Alturas Lake

Estimates of Alturas Lake total O. nerka population, density, and biomass for September 1994 represent a decline of approximately 88% over fall estimates for the previous year. Since 1990, population estimates have declined by over 95%. Growth is the slowest we have documented for any of the Stanley Basin lakes. Juvenile recruitment and spawner escapement during this time period have exhibited considerable variability. In both 1991 and 1992, SBT biologists estimated recruitment to Alturas Lake at approximately 7,000 fish (Spaulding 1993). Late winter conditions hampered efforts to collect recruitment data in 1993. Based on egg-to-fry survival and 1992 escapement, however, the SBT projected 1993 recruitment at approximately 1,000 fish (Teuscher and Taki 1994). In 1994, recruitment was estimated at 2,100 fish (TOC Minutes -July 1994). Young-of-the-year, however, are not being detected in fall trawl surveys. Trawl data from the past four years indicates that recruiting O. nerka have experienced very high mortality or, are just not being sampled by our gear. In 1991, less than 5% of the total September population estimate consisted of age 0+ fish. In 1992, 1993, and 1994, no age 0+ O. nerka were captured in September trawls. An estimated 62, 200, and 3,000 adult spawners escaped to Alturas Lake Creek in 1992, 1993, and 1994, respectively (TOC Minutes - October 1994). The increase in Alturas Lake Creek spawner escapement observed in 1994 reflects the strong year-class strength of age 2+ and 3+ fish detected during the September 1993 trawl. Ninety-seven percent of the September 1993 Alturas Lake trawl catch consisted of these two age-classes (47,811 ± 13,500 fish). Based on September 1994 trawl data, 1995 projected escapement to Alturas Lake Creek is expected to be lower. The trawl population estimate for age 2+ and 3+ fish (combined) was 5,785 (± 6,919) fish and accounted for 100% of the total estimate.

Adult escapement and trawl population data suggest that 1995 recruitment to Alturas Lake will be comparatively high. Much of this production should also be detected in the September population estimate of age 0+ fish. Alturas Lake O. nerka year-class distribution, however, has not looked full for the past three years. The apparent failure of young-of-the-year, beginning in 1992, should begin to impact escapement beginning this year (age 3+ fish) and continue to effect recruitment through at least 1998. Koenings and Burkett (1987) and Koenings and Kyle (1994) documented similar responses in lakes where zooplankton resources had become depressed by excessive planktivory. Delayed recovery of over-grazed zooplankton resources caused reduced rearing efficiency for ensuing broods.

Pettit Lake

Pettit Lake trawl data from September 1994 indicate the total O. nerka population has increased approximately four-fold from 1992; the first year of Pettit Lake data collection. Age 0+ fish captured in the trawl were small in comparison to Redfish and Alturas lake young-of-the-year. These data suggest the possibility of late emergence and recruitment to the limnetic community. The SBT has not been able to document spawn timing for Pettit Lake O. nerka. Their hypothesis that Pettit Lake supports a late season, beach spawning community is supported by our observation of small age 0+ fish. September trawl data from 1992 and 1993 also indicate that young-of-the-year O. nerka were comparatively small. We captured two age 3+ O. nerka during the September 1994 trawl. Subsequent inspection during the removal of ageing structures and tissues for genetic evaluation identified one of these fish as a pre-spawn female. The relatively advanced stage of egg development we observed supports the hypothesis of a late-spawning population.

Pettit Lake is relatively productive in comparison to Redfish and Alturas lakes (Teuscher and Taki 1994). Comparatively fast growth is observed in older lake year-classes captured in the September trawl; this growth is reflected in Pettit Lake's comparatively high estimated lake biomass (4.40 kg/ha). Redfish and Pettit lake O. nerka densities, estimated from September 1994 trawl data, were comparable (125.1 and 128.2 fish/hectare, respectively). However, the estimated O. nerka biomass of Pettit Lake was approximately two times greater than the estimated biomass of Redfish Lake (2.1 kg/hectare).

The trend of increasing numbers of fish, density, and biomass observed in Pettit Lake since 1992 has, to date, been accommodated by the lake's ability to produce food resources. We have not observed density-dependent growth compensation or year-class failure as reported above for the Alturas Lake O. nerka population.

Stanley Lake

The estimated 1994 total O. nerka September population of Stanley Lake increased approximately two-fold over the 1993 estimate. With the exception of 1994 data from Alturas Lake, Stanley Lake exhibits the lowest total population, density, and biomass of the four basin lakes investigated. These data have been consistently low since the initiation of Stanley Lake trawling in 1992. Biomass estimates for Stanley lake are among the lowest in the State for oligotrophic waters supporting kokanee (Rieman and Myers 1991). Age 0+ and 1+ fish comprised 100% of the 1994 trawl sample. In 1992 and 1993, no age 0+ fish were captured in the trawl, however, age 1+ fish accounted for 90% and 54% of the catch for both years, respectively. The absence of older age-classes in our trawl catch may reflect physical limitations encountered during sampling. The relatively shallow depth and small size of Stanley Lake requires that trawl transects be restricted to the center of the lake along one axis. In addition, only one step is generally fished for each transect due to the short axis length of the lake.

We observed a wider range in the size of age 0+ fish from Stanley Lake than from Redfish and Pettit lakes. Spawning surveys of Stanley Lake Creek conducted by the SBT in mid-October were successful in identifying the presence of a small stock of late spawning O. nerka (TOC Minutes - October, 1994). October gill net surveys conducted by the SBT were also successful in capturing five mature O. nerka females (TOC Minutes - October, 1994). The presence of early and late spawning components is thought to be responsible for the wide range in size of the young-of-the-year captured in the trawl.

Sampling Limitations

Midwater trawling remains one the best methods of active sampling for obtaining information on population size, age structure, and stock discrimination for limnetic species. However, several limitations associated with this methodology could affect the quality of the data. Trawling may not accurately reflect all size classes within a targeted population. Rieman (1992) suggests that trawling at speeds of approximately 1 m/s yield reliable estimates of abundance for fish between 50 mm and 220 mm in length. Small individuals (<50 mm) may not be fully represented in the trawl as they might pass through the mesh and avoid capture. Conversely, large individuals (>220 mm) might simply avoid the net, particularly as it is being retrieved. The significance of this potential limitation as it relates to our data is unknown. Trawl estimates should not be used as true estimates of population number or density due to the aforementioned limitations. In general, trawl-based estimates represent some degree of underestimation of true population characteristics. Beginning in 1993, hydroacoustic estimates of Stanley Basin lake O. nerka populations were initiated by the SBT. Hydroacoustic stock assessment can be used to complement population and density estimates from trawling (Parkinson et al. 1994). Emphasis will be placed on comparing the effectiveness of both methods of stock assessment in the future.

Time of year selected for trawling might also bias data. With respect to Idaho waters, kokanee stocks in Redfish and Alturas lakes are characterized as "early spawning". Stanley Lake supports primarily early spawners, however, a small stock of late spawning O. nerka has been identified. Pettit Lake is thought to support late spawning kokanee, however, this hypothesis has not been validated by direct observation. The comparatively small size of young-of-the-year detected in the September Pettit Lake trawl suggests that spawning occurs primarily under the ice in late fall and early winter. Early spawners are generally absent from nursery lakes as early as the beginning of August. Naturally, the majority of these individuals are lost to the trawl once they begin their migration into lake tributaries. Emergent fry generally recruit to the lake between late April and July. There is some question, however, as to when they fully recruit to the limnetic community. Spring trawling will potentially sample older age-classes yet under sample the not-yet-recruited age 0+ component. Fall sampling will not capture older age-classes lost to early spawning but will more accurately reflect numbers of recently recruited age 0+ fish. Biomass estimates will also vary by time of year sampled. Late season or fall sampling will reflect fish condition at the end of the growing season (e.g. greater biomass). Fall trawl dates will also take advantage of the time of year when O. nerka patterns of vertical distribution are relatively narrow. In most cases, except where noted, our data reflect late August through late September (fall) sampling.

Trawl estimates of population and density improve with increasing precision. To achieve reliable estimates of number and density of fish by age-class, multiple trawl transects are generally required. Rieman (1992) suggests that a minimum of seven transects be employed whenever possible. Generally, increasing the number of trawl transects has the effect of reducing the sample variance associated with estimates of total population and density. As the number of transects increase, poor individual transect variance is frequently compensated for. In 1994, we generally fished five transects per lake, per night.

Outmigrant Enumeration

Monitoring O. nerka outmigrant runs from Stanley Basin lakes will play an increasingly important roll in recovery efforts as captive broodstock progeny are outplanted to mature and migrate volitionally. Information collected from Redfish and Alturas lake outmigrants has contributed to our knowledge of outmigrant characteristics and provided insight into continuing efforts to differentiate stocks. Outmigrant O. nerka captured between 1991 and 1993 also represent a major element in the captive broodstock recovery program.

Redfish Lake Creek Trap

The number of O. nerka estimated to have outmigrated from Redfish Lake in 1994 increased three-fold over the 1993 estimate. As no anadromous sockeye salmon have spawned in Redfish Lake since 1989, outmigrants from 1993 and 1994 are progeny of either the beach-spawning residual sockeye salmon or Fishhook Creek-spawning kokanee stocks of Redfish Lake (assumes that outmigration year 1992 is the last year associated with the production of outmigrants with direct lineage to anadromous parents). At the present time, we do not know what relative contributions are being made by residual sockeye salmon or resident kokanee with respect to the production of outmigrants. However, the current line of thinking is that residual progeny represent a significant component of the outmigration. The three-fold increase observed in 1994 outmigration run size is difficult to speculate on without further knowledge of outmigrant lineage or residual spawner escapement. If outmigrants are largely the progeny of residual beach spawners, their numbers should remain depressed as fewer than 100 adults were estimated to have spawned in 1993 and 1994 (Teuscher and Taki 1995).

Efforts to enumerate outmigration from Stanley Basin lakes prior to 1991 are scarce. Between 1955 and 1966, Bjornn et al. (1968) operated a two-way weir on Redfish Lake Creek collecting information on adult escapement as well as juvenile outmigration. During this period, they observed a range in Redfish Lake outmigrant run size from 2,133 fish (1960) to 65,000 fish (1957). Estimates of outmigrant run size exceeded 20,000 fish in seven of their 12 years of investigation. Bjornn et al. (1968) observed peak outmigration to occur during the first three weeks of May. In 1994, we observed the largest numbers of fish leaving Redfish Lake during this same time period. Outmigration data from 1991 through 1993 generally conform to this pattern as well.

Much has been written on the relationship between the age at which juvenile sockeye salmon migrate and their growth during their first summer in the lake. Foerster (1968) noted that the number of sockeye salmon that remain in lakes for more than one year prior to seaward migration are not numerous in most of the prominent sockeye salmon rivers of British Columbia. In cases where age 2+ smolts are observed, the evidence suggests that the rate of growth is so slow that the young sockeye salmon are not sufficiently developed at the end of their first year to be stimulated to migrate seaward. Koenings and Burkett (1987) presented an empirical classification of sockeye salmon smolt production related to population characteristics for coastal and interior Alaskan Lakes. They determined that sockeye salmon smolts from rearing-limited lake systems were frequently older and larger as a result of density-dependent rearing conditions. Bjornn et al. (1968) reported that juvenile sockeye salmon migrated from Redfish Lake at the beginning of their second (1+) or third (2+) summer of life. During their period of investigation, the percentage of age 1+ outmigrant smolts varied from 2% to 98%. They concluded that if population density was low and growth good, juvenile sockeye salmon would likely outmigrate as age 1+ fish. If growth was slow, due to high population density, the chances were increased the fish would remain in the lake a second year. Since 1991, rearing conditions in Redfish Lake have favored the production of age 1+ outmigrants. The largest number of age 2+ outmigrants was recorded in 1992 when 15% of the run consisted of this age-class.

Adult escapement between 1955 and 1966 ranged from 11 fish (1961) to 4,361 fish (1955) (Bjornn et al 1968). Adult returns exceeded 300 fish in six of the 12 years investigated. In 1991, adult sockeye salmon access to Redfish Lake was circumvented by the installation of an upstream adult trap on Redfish Lake Creek; an integral component of the present recovery effort. Prior to 1991, IDFG did not operate the trap and adult sockeye salmon escapement to the lake was possible. Based on adult detections at LGrD, no sockeye salmon were believed to have reached Redfish Lake in 1990. In 1988 and 1989, 23 and two adult sockeye salmon, respectively, were detected at LGrD. Actual observations of sockeye spawning in Redfish Lake for this period are scarce, however, it is likely that successful lake spawning did occur in 1988 and 1989 (Hall-Griswold, 1990).

The anadromous female sockeye salmon that returned to Redfish Lake in 1994 was aged at 4+ years. We did not attempt to identify her age at outmigration or the number of winters she spent in seawater. Two possible scenarios prevail, however, to describe this individual's life history: (1) outmigration at age 1+ with three winters of seawater life (1.3+ age at return), and (2) outmigration at age 2+ with two winters in the ocean (2.2+ age at return). Regardless of specific life history, an age 4+ fish would have been produced in brood year 1989, the last year thought to support lake spawning by anadromous adults.

We observed relatively high total PIT tag detections in 1991 and 1993 at downstream Snake and Columbia River dams for Redfish Lake O. nerka smolts (57% and 44%, respectively). Total PIT tag detections recorded in 1992 and 1994 for Redfish Lake releases were lower (22% and 21% respectively). The observed high level of 1991 detections for Redfish Lake outmigrants agrees with data reported by Kiefer and Lockhart (1993). In 1991, they noted increased downstream dam detections for chinook salmon smolts released from the Sawtooth weir. Kiefer and Lockhart (1993) associated this increase in detections with elevated mainstem streamflows that occurred during outmigration. Relatively high spring runoff occurred again in 1993, the second highest detection year for our data set.

Sawtooth Hatchery Trap

Alturas Lake outmigrant run size was estimated at 8,000, 914, 2,720, and 0 fish for the years 1990 through 1993, respectively. In 1994, we estimated that 945 juvenile O. nerka emigrated from Alturas Lake. Age analysis of 1991 and 1992 Alturas Lake outmigrants indicated that the majority of smolts left the lake as age 2+ fish (brood years 1988 and 1989, respectively). Alturas Lake trawl data from 1990 and 1991 reflected very high O. nerka total densities. Considering the present strategy of age 2+ outmigration, emigrants produced by spawners in both years of high fish density would have outmigrated from Alturas Lake in 1993 and 1994. As indicated above, zero and 945 juvenile O. nerka, respectively, outmigrated during these years suggesting very poor survival of the 1990 and 1991 year-classes. It is reasonable to assume that strong density-dependent rearing conditions developed following brood years 1990 and 1991.

In 1994, we estimated the age-class 0 and 1 components of the Alturas Lake population at zero fish. Because these year-classes will produce 1995 outmigrants, it is reasonable to assume that the 1995 outmigration from Alturas Lake will remain depressed.

The availability of lower Snake River PIT tag detection data for Sawtooth FH weir releases is limited to 1992 and 1994 when total detection rates of 11% and 0%, respectively, were noted for O. nerka smolts presumably of Alturas Lake origin. Alturas Lake outmigrant detections in 1992 were 50% lower than Redfish Lake detections for the same year. In 1994, no Alturas Lake outmigrants were detected downstream compared to a 21% total detection rate for Redfish Lake outmigrants. Although only two years of data are available for direct comparison, this difference in detection rates suggests that O. nerka emigrants from Alturas Lake do not survive migration to mainstem dams as well as outmigrants from Redfish Lake (assuming similar outmigration and arrival timing).

Natural Spawning Investigations

Telemetry investigations conducted on Redfish Lake in 1994 generated information relevant to evaluating performance differences observed among adult broodstock releases with differing life histories and broodstock origins. In addition, the future direction and design of this release strategy will depend, in part, on the data collected to date.

Telemetry investigations of 24 ultrasonic-tagged, captive broodstock adults released to Redfish Lake in 1993 identified three general areas of site selection: (1) Sockeye Beach, (2) Point Campground, and (3) the southwest shore (Kline 1994). During November 1993 snorkel investigations, one pair of broodstock outplants was observed guarding a redd near the southwest shore of the lake (TOC Minutes - November, 1993). Two transmitters were subsequently located in the vicinity of this activity.

During 1994 telemetry efforts, we made no observations of sustained site association or spawning-related activities for any of the 37 ultrasonic-tagged release fish. Additionally, no stationary tags were located near areas of known or suspected spawning activity. At the termination of 1994 telemetry efforts, 29.7% of the transmitters (11 of 37 tags) were still active. Kline (1994) reported similar findings (33.3% active, eight of 24 tags) at the termination of the 1993 tracking investigation. Active signals most likely represent broodstock fish that did not mature. While very limited observations of spawning-related activity were observed during both years of investigation, we can not assume that additional activity and spawning success did not occur. The weekly periodicity of SBT and IDFG spawning surveys does suggest that spawning-activities could simply have been missed. Recovered transmitters represent the only known mortalities. Absent transmitter signals could represent additional mortality, tag failure, poor or obscured signal strength, fish migration to tracking-restricted locations (e.g., inlet and outlet streams), or out-of-lake transmitters. Predation and illegal angler harvest are suspected as possible explanations for absent transmitter signals. One report of one angler catching and releasing what was reportedly a broodstock outplant was received by IDFG in 1994 (Brent Snyder, IDFG, Stanley, Idaho). Although Redfish Lake receives limited angling effort, the possibility remains that additional broodstock outplants were lost to illegal angling harvest. Stationary signals could represent additional mortality, out-of-fish transmitter status, or stationary fish. The latter condition was carefully investigated during both years of this effort. Transmitters identified as stationary rarely initiated movement following three successive weeks of stationary status. We suggest that stationary signals represent out-of-fish transmitter status. However, without knowing if tag expulsion occurred (or to what degree), we cannot speculate further as to whether out-of-fish signals represent mortalities.

The performance differences we identified with respect to final transmitter status for brood year 1991 and outmigrant 1991 outplants are significant, yet, irresolute. In addition to the many possible interpretations of final tag status discussed above, brood year 1991 and outmigrant 1991 broodstock outplants differed significantly with respect to mean fork length and weight. Individuals in the apparently more successful outmigrant 1991 group were also two years older than the brood year 1991 fish. The extent to which these differences biased our ability to interpret performance based on genetic broodstock origin is unknown. Although many conditions exist to shroud our test of the final tag status data (many of which could arguably invalidate the premise for testing) the fact remains that outmigrant 1991 broodstock outplants exhibited lower incidences of stationary and absent tag status (potential mortality indices) and a markedly higher incidence of active tag status than brood year 1991 fish.

Predator Investigations

Trap net sampling in 1994 represents the second consecutive year of Redfish Lake predator fish investigations. In compliance with the Biological Opinion issued to IDFG by NMFS permitting this activity, 1994 efforts did not utilize gill nets. In addition, no capture gear was set in close proximity to the mouth of Fishhook Creek. We did not attempt to mark bull trout for mark-recapture population purposes as it was evident, after initial trap tending, that we would not be able to capture adequate numbers of fish. We were also required to discontinue the investigation following the second night of net sets due to the capture of wild and hatchery-released O. nerka.

Relative species abundance and catch rate data from 1994 trap net efforts were similar to gill net data reported by Kline (1994) and Liter and Lukens (1992) for 1993 and 1991 investigations, respectively. Bull trout comprised 5.4%, 5.1% and 2.4% of the total catch for years 1991, 1993, and 1994, respectively. Trap nets proved to be less successful than gill nets at capturing bull trout. In 1994, we observed a catch rate of 0.04 bull trout per trap net hour compared to the 1993 catch rate of 0.10 bull trout per gill net hour reported by Kline (1994). Northern squawfish comprised 6.5%, 1.6%, and 4.2% of the total catch in 1991, 1993, and 1994, respectively.

Bull trout and northern squawfish captured by trap netting in 1994 were considerably smaller than 1991 and 1993 gill net captured fish. This is most likely attributable to differences in location and water depth fished by the different gear. Trap nets were restricted to shallow water immediately adjacent to shore. Gill net sets extended farther out from the shore and fished deeper water. Because of their small size (fork length range 120 mm - 288 mm), we did not attempt to evacuate the stomach contents of bull trout captured in 1994. The lavage equipment (turkey baster) was considered too large, relative to the buccal cavity and pharyngeal opening of captured fish. Kline (1994) reported a 50% level of mortality for bull trout captured by gill netting in 1993. Five of the six fish captured that year were subjected to lavage procedures.

Trap nets did not represent a mortality risk to captured fish. They did, however, prove to be effective at capturing O. nerka. In 1994, trapping efforts coincided with residual sockeye salmon spawn timing in Redfish Lake. Our rationale for conducting the investigation during this period revolved around our knowledge of the spawn timing of Redfish Lake bull trout. An unknown percentage of the adult bull trout population is essentially lost to all capture efforts between August and early October as they ascend Fishhook Creek to spawn. A portion of the spawners may also emigrate from Redfish Lake seeking mainstem and tributary spawning areas of the upper Salmon River. While late October represents a desirable time frame in which to capture bull trout, trap netting during this time of the year appears to be less acceptable because of the potential for capturing O. nerka, an action in direct conflict with the terms and conditions of the NMFS Biological Opinion.

Trap netting following ice-out might also prove unacceptable as O. nerka recruit to the lake from Fishhook Creek and lake shore spawning areas in early spring. Sockeye and kokanee fry remain littoral for an unknown period of time following their emergence and introduction to the lake community. During this time, they could be particularly susceptible to capture gear set in shallow water adjacent to the shore. Trap nets typically have smaller mesh in the containment area than on the lead or at the opening. Juvenile O. nerka that do not avoid the larger entry mesh could become trapped in the containment area.

Future efforts to estimate the bull trout population in Redfish Lake should concentrate on looking at specific life history aspects of the species during its association with Fishhook Creek. Adult spawner counts, redd counts, fecundity and egg-to-fry survival estimates could provide enough information to formulate an index of production. By answering questions about consecutive year spawning, term of stream residency by juveniles, and in-stream mortality, an estimate of bull trout recruitment to the lake could be generated.

Parental Lineage Investigations

During the development of ova, vitellogenesis in anadromous fish begins while the female parent is in the ocean. Conversely, this process occurs entirely in freshwater for non-anadromous, non-marine species. Strontium can partially substitute for Ca in the formation of vitellogenin, the precursor to yolk in developing ova. As development continues, Sr can partially substitute for Ca in the aragonite matrix of the first calcified structures to form; the otolith primordia. As fish grow, Sr continues to interchange with Ca in the depositional process of otoliths (Kalish 1989,1990; Radtke 1989). Kalish (1990) and Rieman et al. (1993) concluded that Sr/Ca ratios in otoliths and ova reflect the relative amounts of Sr and Ca in the environment. Typically, Sr/Ca ratios are higher for marine waters than for fresh waters (Kalish 1990; Rieman et al. 1993).

Otolith microchemistry has been used to discriminate individual fish from female parents of known anadromous and freshwater origin. Kalish (1990) reported that differences between Sr/Ca ratios in otolith primordia of sea-farmed and freshwater juvenile rainbow trout were great enough to identify individual life history (with respect to habitat location) during egg development. Mean nuclear Sr/Ca ratios reported by Kalish (1990) were between 0.0022 and 0.0052 for the progeny of sea-farmed rainbow trout. Rieman et al. (1993) reported mean nuclear Sr/Ca ratios between 0.0011 and 0.0020 for O. nerka progeny with known lineage to anadromous adults. Secor et al. (1994) used otolith microchemistry to describe the environmental life history of individual striped bass Morone saxatilis across a salinity gradient. They reported that mean nuclear Sr/Ca ratios between 0.0020 and 0.0030 were indicative of estuarine salinities and ratios >0.0035 were indicative of marine salinities.

Rieman et al. (1993) observed mean nuclear Sr/Ca ratios >0.0014 in otoliths of the five anadromous adults that returned to Redfish Lake in 1991 and 1992. They concluded that all five adult sockeye salmon were direct descendants of female anadromous parents that completed egg development in saltwater. Kline (1994) reported, however, that two of the eight anadromous adults that returned in 1993 exhibited microchemistry results suggesting direct lineage to freshwater female parents (<0.0008). Kline (1994) speculated these data could link anadromous adults to the freshwater residual O. nerka component of Redfish Lake. One of the eight anadromous adults analyzed by Kline (1994) exhibited mean, nuclear Sr/Ca results indicative of uncertain lineage (0.0008 - 0.0014).

Otolith microchemistry results from the one anadromous female sockeye salmon that returned to Redfish Lake in 1994 reflected direct lineage to an anadromous female parent (mean nuclear Sr/Ca >0.0014). The age of this individual (4+)

links it to brood year 1989, the last year anadromous sockeye salmon had access to Redfish Lake.

Otolith microchemistry results from 54 progeny of the one anadromous female sockeye salmon that returned to Redfish Lake in 1991 produced results consistent with our expectations. In all cases, mean Sr/Ca ratios observed in otolith nuclei agreed with the findings of Rieman et al. (1993) and Kline (1994). We anticipated this level of agreement as otolith samples analyzed in this report, by Rieman et al. (1993) and by Kline (1994) were extracted from progeny of the same anadromous female sockeye salmon. These data indicate that wavelength dispersive electron microprobe analyses of like-origin otoliths produce repeated measures of consistent results over time.

Otolith microchemistry results from the 11 brood year 1993 progeny (progeny of the 2 female and 6 male sockeye salmon that returned to Redfish Lake in 1993) produced nuclear Sr/Ca ratios less consistent with our expectations. Thirty-six percent (four of 11 samples) of the results from this group fell below 0.0014 indicating some deviation from the data set established by Rieman et al. (1993) and supported by Kline (1994). A number of biological factors, including stress and changing metabolic rate, may influence the substitution of Sr for Ca in developing otoliths (Kalish 1989). During the transition from saltwater to freshwater, anadromous salmonids are affected by these and other factors that could influence this process. The anadromous female parents of the progeny investigated in this report all moved into freshwater at some time during, or after, egg development. Mean Sr/Ca ratios observed in these adults reflect the possibility that ova development was not complete at the time fish entered freshwater (other biological factors aside). Kalish (1990) suggested that the development of ova in anadromous salmonids is virtually complete before the fish enter fresh water. Our data suggest the possibility that this is not necessarily correct, or, that other biological factors are operating to overshadow the effects of changing salinity on the uptake of Sr in developing ova.

Rieman et al. (1993) and Kline (1994) observed a range in mean nuclear Sr/Ca data for 1991 Redfish Lake outmigrants suggesting direct lineage to both freshwater (Sr/Ca <0.0008) and saltwater (Sr/Ca >0.0014) female parents. Approximately one-third of their results, however, were regarded as equivocal (Sr/Ca 0.0008 - 0.0014) based on microchemistry data from progeny of known saltwater and freshwater origin. The data collected in this study indicate that Sr/Ca ratios observed in otolith nuclei of progeny with known lineage to anadromous female sockeye salmon range between 0.0008 - 0.0020. Increasing the sample size of otolith microchemistry data for progeny associated with known life history will help refine our interpretation of the origin of Stanley Basin _O. nerka_ with uncertain life history. Along with genetic data, otolith microchemistry will assist in the process of documenting the relative contribution that Stanley Basin lake natural production plays in generating outmigrant smolts. As adults of uncertain origin return to Stanley Basin lakes, otolith microchemistry will play an increasingly important role in the identification of their life history and provide perspective on the success of sockeye salmon supplementation efforts.

RECOMMENDATIONS

1) We were unsuccessful at documenting association with known or suspected spawning habitat, staging, or spawning for any of the broodstock adults released to Redfish Lake in 1994. While we suspect that weekly observations should be adequate to detect spawning-related activities if they are occurring, we recommend that more frequent observations be made if this release strategy is repeated in the future.

2) Trap nets and gill nets have been unsuccessful at capturing sufficient bull trout to enable an estimate of population size. Additionally, _O. nerka_ are

susceptible to capture by trap nets and gill nets are presently restricted from use by NMFS. As an immediate means of tracking bull trout reproduction potential and trend, we recommend that adult spawner counts and redd counts be initiated in Fishhook Creek to establish baseline data in this regard.

3) We recommend that additional otolith microchemistry data be collected for O. nerka progeny associated with known life history to help refine our interpretation of the origin of Stanley Basin O. nerka with uncertain life history.

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A P P E N D I C E S

Appendix A. Length, weight, lineage, and sex information for 1994 ultrasonic-tagged adult captive broodstock O. nerka outplants to Redfish Lake. OM91 = 1991 outmigrants. OM92 = 1992 outmigrants. BY91 = progeny of 1991 anadromous adults.

Codes[a]	Length[b] (mm)	Weight (g)	Lineage	Sex
97	555	2898	OM91	FM
13-3	610	3480	OM91	FM?
266	570	3070	OM91	FM
366	590	3074	OM91	M
455	570	2920	OM91	M
464	575	2910	OM91	FM
473	555	2580	OM91	FM
2228	595	3346	OM91	FM
2237	610	2000	OM91	M
2345	600	2732	OM91	M
2354	560	2862	OM91	M
2363	670	4310	OM91	M
2435	555	2372	OM91	M
2543	540	2410	OM91	FM
2633	528	2778	OM91	M
14-2	490	1516	OM92	FM
356	538	2118	OM92	FM
88	520	2200	BY91	FM
10-6	540	2250	BY91	FM
11-5	520	2190	BY91	FM
12-4	520	2215	BY91	FM
239	540	2440	BY91	M
248	540	2278	BY91	FM
285	480	1520	BY91	FM
293	510	1980	BY91	FM
338	595	3220	BY91	FM
347	515	2158	BY91	FM
374	580	3200	BY91	M
365	535	2092	BY91	FM
446	537	2704	BY91	FM
554	590	2890	BY91	M
555	580	2860	BY91	M
2273	535	2286	BY91	FM
2426	590	3090	BY91	M
3335	454	2642	BY91	M
3344	545	2390	BY91	FM
3434	530	2250	BY91	FM

[a] Frequencies are 70 to 76 Khz ± 2 Khz
[b] Fork length

Appendix B. Age, weight, and fork length of O. nerka captured in fall 1994 midwater trawls of four Stanley Basin lakes. RFL = Redfish Lake, ALT = Alturas Lake, PET = Pettit Lake, STA = Stanley Lake.

Lake/Fish No	Age	Weight (g)	Fork Length (mm)
RFL/01	0+	0.5	36
RFL/02	0+	0.7	41
RFL/03	0+	0.8	42
RFL/04	0+	1.1	42
RFL/05	0+	0.8	42
RFL/06	0+	0.8	43
RFL/07	0+	0.8	43
RFL/08	0+	0.8	44
RFL/09	0+	0.9	44
RFL/10	0+	0.9	44
RFL/11	0+	1.1	45
RFL/12	0+	0.9	45
RFL/13	0+	1.2	46
RFL/14	0+	1.1	47
RFL/15	0+	0.9	47
RFL/16	0+	1.0	47
RFL/17	0+	1.2	52
RFL/18	0+	1.3	53
RFL/19	0+	1.5	54
RFL/20	0+	1.9	55
RFL/21	0+	1.8	55
RFL/22	0+	2.2	58
RFL/23	0+	2.2	60
RFL/24	0+	2.5	62
RFL/25	0+	2.1	62
RFL/26	0+	3.3	66
RFL/27	1+	4.8	78
RFL/28	1+	5.3	81
RFL/29	1+	5.8	82
RFL/30	1+	7.5	89
RFL/31	1+	18.2	118
RFL/32	2+	34.6	144
RFL/33	2+	41.6	150
RFL/34	2+	43.7	154
RFL/35	2+	47.8	156
RFL/36	2+	48.6	157
RFL/37	2+	53.1	161
RFL/38	2+	49.9	163
RFL/39	2+	51.6	165
RFL/40	2+	54.2	167
RFL/41	2+	56.1	168
RFL/42	2+	54.9	174
RFL/43	2+	65.1	179
RFL/44	2+	63.7	183

Appendix B. Continued.

Lake/Fish No	Age	Weight (g)	Fork Length (mm)
ALT/01	2+	17.8	123
ALT/02	2+	20.4	125
ALT/03	2+	21.2	129
ALT/04	2+	22.2	136
ALT/05	2+	24.0	138
ALT/06	2+	25.4	139
ALT/07	3+	25.6	137
ALT/08	3+	27.3	138
ALT/09	3+	28.1	138
ALT/10	3+	27.3	139
ALT/11	3+	29.3	143
ALT/12	3+	29.6	146
PET/01	0+	0.1	24
PET/02	0+	0.4	35
PET/03	0+	0.4	39
PET/04	0+	0.5	39
PET/05	0+	0.5	39
PET/06	0+	0.5	39
PET/07	0+	0.6	40
PET/08	0+	0.6	40
PET/09	0+	0.7	40
PET/10	0+	0.7	41
PET/11	0+	0.8	43
PET/12	0+	0.9	43
PET/13	0+	1.1	44
PET/14	0+	0.8	44
PET/15	0+	1.5	54
PET/16	0+	0.9	44
PET/17	1+	18.3	116
PET/18	1+	24.3	125
PET/19	1+	21.6	126
PET/20	1+	24.7	128
PET/21	1+	28.0	129
PET/22	1+	28.7	129
PET/23	1+	26.7	130
PET/24	1+	27.9	131
PET/25	1+	29.6	131
PET/26	1+	29.2	132
PET/27	1+	28.9	133
PET/28	1+	29.2	134
PET/29	1+	28.6	135
PET/30	1+	38.0	137
PET/31	1+	30.1	139
PET/32	1+	32.6	140
PET/33	1+	34.8	142
PET/34	1+	37.3	142
PET/35	1+	34.2	144
PET/36	1+	35.6	144
PET/37	1+	38.4	144
PET/38	1+	33.8	144
PET/39	1+	42.6	145
PET/40	1+	39.7	146
PET/41	1+	37.5	147

Appendix B. Continued.

Lake/Fish No	Age	Weight (g)	Fork Length (mm)
PET/42	2+	44.9	150
PET/43	2+	43.9	150
PET/44	2+	42.1	150
PET/45	2+	42.7	151
PET/46	2+	48.3	153
PET/47	2+	46.0	153
PET/48	2+	43.1	154
PET/49	2+	43.1	154
PET/50	2+	52.5	156
PET/51	2+	53.5	159
PET/52	2+	54.0	159
PET/53	2+	54.5	159
PET/54	3+	189.4	237
PET/55	3+	305.9	265
STA/01	0+	1.4	52
STA/02	0+	2.2	54
STA/03	0+	2.7	69
STA/04	0+	3.1	70
STA/05	0+	4.3	73
STA/06	0+	5.1	75
STA/07	0+	6.3	76
STA/08	0+	5.2	78
STA/09	0+	6.8	82
STA/10	0+	6.7	83
STA/11	0+	7.8	85
STA/12	0+	6.5	85
STA/13	0+	6.7	85
STA/14	0+	8.1	88
STA/15	1+	36.1	150
STA/16	1+	40.0	154
STA/17	1+	41.6	155
STA/18	1+	47.0	162

Appendix C. Mean Sr/Ca ratios and standard deviations measured in otolith nuclei from Redfish Lake O. nerka with differing life histories. Fish ID indicates life history (BY91 = brood year 1991 progeny of 1991 anadromous adult returns, BY93 = brood year 1993 progeny of 1993 adult returns, AN94 = 1994 female adult return).

Fish ID	Nuclear Sr/Ca	SD
AN94-565	0.001456	0.000142
BY91-1	0.001774	0.000094
BY91-2	0.001715	0.000132
BY91-3	0.001937	0.000200
BY91-8	0.001812	0.000081
BY91-9	0.001669	0.000142
BY91-10	0.001832	0.000124
BY91-11	0.001929	0.000103
BY91-12	0.001849	0.000149
BY91-13	0.002104	0.000099
BY91-14	0.001839	0.000115
BY91-15	0.002061	0.000063
BY91-16	0.001953	0.000140
BY91-17	0.001787	0.000124
BY91-18	0.001729	0.000148
BY91-19	0.001964	0.000103
BY91-20	0.001972	0.000082
BY91-21	0.001888	0.000131
BY91-22	0.001870	0.000163
BY91-24	0.001911	0.000103
BY91-25	0.001913	0.000078
BY91-26	0.001937	0.000142
BY91-27	0.001896	0.000140
BY91-28	0.001934	0.000124
BY91-29	0.002009	0.000124
BY91-30	0.001828	0.000154
BY91-31	0.001935	0.000115
BY91-32	0.001909	0.000078
BY91-33	0.001755	0.000117
BY91-34	0.001840	0.000096
BY91-35	0.001945	0.000084
BY91-36	0.001906	0.000094
BY91-37	0.001924	0.000117
BY91-38	0.001875	0.000094
BY91-39	0.001887	0.000133
BY91-40	0.001961	0.000096
BY91-41	0.002001	0.000115
BY91-42	0.001936	0.000096
BY91-43	0.002020	0.000073
BY91-44	0.001827	0.000141
BY91-45	0.001768	0.000113
BY91-46	0.002058	0.000082
BY91-47	0.001935	0.000157
BY91-48	0.001818	0.000132
BY91-49	0.001969	0.000141
BY91-50	0.001973	0.000082
BY91-304	0.001894	0.000081
BY91-305	0.001787	0.000091
BY91-307	0.001846	0.000117
BY91-308	0.001772	0.000070
BY91-309	0.001791	0.000119
BY91-310	0.001794	0.000073
BY91-312	0.001878	0.000078

Appendix C. Cont.

Fish ID	Nuclear Sr/Ca	SD
BY91-313	0.001697	0.000155
BY91-314	0.001940	0.000115
BY93-1	0.001734	0.000094
BY93-3	0.001645	0.000117
BY93-4	0.001665	0.000105
BY93-5	0.001770	0.000188
BY93-6	0.001307	0.000144
BY93-7	0.001089	0.000115
BY93-8	0.001083	0.000109
BY93-9	0.000801	0.000128
BY93-10	0.001742	0.000126
BY93-11	0.001625	0.000296
BY93-12	0.001560	0.000117

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